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THE MECHANISM OF WEAVING

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THE MECHANISM

OF

WEAVING

BY

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PREFACE TO THE FIFTH EDITION

In view of the wide circulation and general popularity which this work has enjoyed, I readily acceded to the request of Mrs. Fox to undertake its revision for a new edition.

In carrying out the task I have endeavoured to make as few alterations as possible to the previous edition, in order that its distinctive character might be preserved.

W. M.

January 1922.

PREFACE TO THE FIRST EDITION

THE hand-loom was a comparatively simple machine, and the beauty of its productions depended chiefly upon the handicraft skill of the weaver; but with the introduction of the power-loom, weaving became a new industry. With new machinery, and new processes, a want of definite information respecting their functions and actions was keenly felt, and books were published which dealt with the more pressing problems. Nevertheless, when an impetus was given to technical education by the establishment of technical schools, the paucity of this class of literature was revealed.

During recent years several admirable books have been written on weaving, but it has been too much the custom to consider designing, fabric structure, and the calculations relating thereto, as the most important parts of the subject. Hence, only one treatise has appeared within the last twenty years in which the mechanical side of weaving has not been subordinated to the structural side.

The present treatise is designed to supply this deficiency, and to place within the student's reach exact and practical information bearing upon the principles of weaving as exemplified in the various processes of the trade. If this book assists in some small degree to give students a better

knowledge of the textile industry, the author will feel that his labour has not been in vain.

Within the compass of this volume it is manifestly impossible to deal fully with all kinds of weaving mechanism. Some branches of weaving have been unavoidably passed over, but an effort has been made to include the leading types of machinery.

The illustrations have been mainly prepared from machines and appliances in the Municipal School of Technology, Manchester.

MANCHESTER, *September* 1894.

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PART I

INTRODUCTION

THE POWER-LOOM

THE construction of an automatic weaving machine has engaged the attention of loom-makers and others for more than a century, during which time much has been accomplished, but much still remains to be done. Many problems have been solved, many are still awaiting solution.

Various causes have retarded the rapid development of the loom, such as the nature and varying weaving capabilities of the material to be manipulated, and defective work in the spinning and preparatory departments, all of which render the application of delicate and sensitive movements essential.

The want of higher training in mechanics has led to the addition of unsuitable parts which, after a trial, had to be discarded. The comparative isolation of loom-maker from loom-user has also placed both at a disadvantage; the one from lack of practical experience in the use of the loom, and the other from lack of mechanical skill to carry out ideas that daily contact with the work suggested. Nevertheless, part after part has been

permanently added as the needs presented themselves, and the credit for such additions must be equally shared by weavers, overlookers, mill managers, manufacturers, and machinists.

The loom is a machine in which a series of intermittent movements are required to control its various parts; and all must be accurately timed and fixed to ensure a regular sequence. The aim should, therefore, be so to unite the parts that one cannot get out of harmony with another; but, after a century spent in developing the loom, its parts are often so imperfectly connected that, on reversing the motion of a slay, some continue to move in their normal direction, while others are reversed. This is a cause of much annoyance and loss of time to the weaver.

Taking-up motions, dobbies, and Jacquard cylinders are the most familiar instances of this; for many looms, provided with specially designed pieces of mechanism, still require the Jacquard cards, the picking-chain, the box-chain, and the taking-up motion to be separately adjusted after unweaving, and before restarting the machine. There are, however, other looms in which all the principal movements are positively controlled.

The mechanisms of a loom are, A, primary,—namely, shedding, picking, and beating-up; B, parts which assist or modify the primary motions, as over and under reversing gear, fast and loose reeds, check straps, buffers, breaks, and shuttle guards; C, secondary motions, as letting off, taking up, shuttle-box, weft stop, warp stop, temples, selvage, and others. In the following pages each part is separately treated with regard to construction, the principles governing it, and the means adopted for uniting all in one machine. Finally, the loom is considered as a whole, and the timing and adjusting of its parts are dealt with.

PART II

HEALDS

WEAVING consists in interlacing two sets of threads, one set placed longitudinally and the other transversely in a fabric. The longitudinal or warp threads having been carefully arranged and evenly wound upon a beam, must be separated into two lines, and a transverse or weft thread passed through the division. It is by the proper selection of warp threads for successive upper and lower lines that patterns are formed in fabrics.

Healds have been employed for many centuries to divide the warp, because under certain conditions they supply the most perfect means of accomplishing the work technically known as shedding. But before healds can be used with advantage, the different kinds available must be described, and the purposes they are intended to serve must be defined.

From the time a heald was first introduced the principle of forming a shed was established, and it only remained for later inventors to improve upon the model and introduce new appliances for actuating it.

The most primitive heald of which there is any record consists of a series of twine loops, each passing round a warp thread and fastened to a wooden rod. The number of loops on a rod, and the number of rods employed, depend upon the breadth and closeness of the warp threads and the order of interlacing them; but for all but plain weaving the loops collectively equal the number of warp threads. A shed is formed by drawing forward the proper

rod, and thus carrying part of the threads across the rest. The rods being moved by the weaver's hands, renders the operation a slow one; still it is vastly more expeditious than the previous method of threading a needle through the warp in a manner analogous to darning.

Fig. 1 shows such a heald; the dots A are cross-sections of warp threads, B is the twine formed into loops, and C is the wooden rod to which the loops are attached. When the rod C is drawn forward, all warp threads controlled by it will be carried in advance of those operated by other rods.

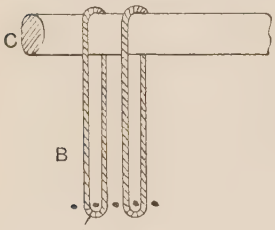


FIG. 1.

The next alteration is said to be of Indian origin, and more than two thousand years old. It is almost as great an improvement upon the primitive heald as the latter was upon older appliances. It is made by linking, or clasping, a second and similar series of loops into those previously described, passing each round a second rod, and securing them to a "ridge band," whose office is to keep each loop in its proper place upon the rods. By the introduction of this simple contrivance the productiveness of a loom was largely increased, for the healds were actuated by the weaver's feet, and his hands were free to control other parts of the machine simultaneously instead of consecutively. Similar healds are still used in different parts of the world, but they have been superseded in Great Britain.

Fig. 2 shows the construction and the method of controlling clasped healds; A, B are two of a series of loops attached to the rods C, D. From rod C a cord F passes over a grooved pulley G to a rod C′, which contains a

similar number of loops. The bottom rods D, D′ are connected by cords to treadles H, H′, and the warp threads E are drawn between the linked loops. When at work the weaver depresses the treadles H, H′ alternately with

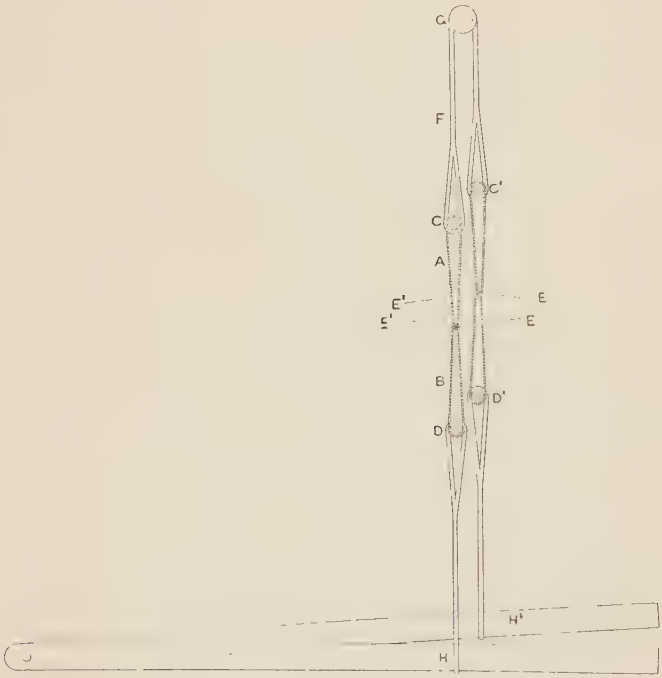


FIG. 2.

his feet. Assuming H to be pressed down, shaft C, D, together with the warp threads passed through its loops, will receive a similar motion; but shaft C′, D′, the warp controlled by it, and the treadle H′, will all move through an equal space in the opposite direction. When the treadle H′ is forced down the position of every part is reversed,

consequently the warp threads can be raised and lowered in a very expeditious manner; but great strain is put upon the warp when a shed is open, owing to the heald loops preventing the threads from making a sliding movement.

In Fig. 2 the healds are placed at right angles to the warp, with one rod above and the other below it, and each shaft is arranged to rise or fall vertically. When the healds are inoperative all warp threads are horizontal, but any movement of the former will bend the latter, and so increase their length between E, E′. It is desirable to leave the threads free to slide in the healds when an upward or downward movement is given to them, but with clasped healds this cannot be done, for the force exerted to move a shaft causes each pair of loops to bear tightly upon the thread between them (see 1, Fig. 3). Where weak or inelastic warps are used excessive breakage results from forming sheds in this manner.

That so many generations of skilled workmen failed to adopt the simple plan now in use, and that it should have required two stages to develop, is remarkable. The first change consisted in doubling the number of loops on each pair of rods, and in causing those loops to lie in two ranges; a warp thread was then passed over one loop and under another, so that as the rods rose or fell the warp was positively moved without undue strain (see 2, Fig. 3). The second change introduced the modern heald, which has been rendered almost perfect by tying a knot at a short distance above the point where the upper loop links with the lower half, thus forming an eye large enough for a thread of warp to move in without being unnecessarily strained. Thin laths have also displaced round rods, as they allow a larger number to be placed side by side in a given space.

No. 3, Fig. 3, shows an eyed heald; B, B′ are loops which, for cotton manufacturing, vary between 10″ and 14″ from top to bottom; C is an eye whose depth is from $\frac{1}{4}$″ for cotton goods to $\frac{5}{8}$″ for silk goods, and D, D are the laths or shafts.

Eyed healds are used in many forms and are of varied materials, as, for example, those where twine loops support a steel, brass, glass, or other metal eye, as at 4, Fig. 3. Such healds are usually employed when rough, knotty warps have to be woven, but glass is principally used for silk and occasionally for cotton gauzes. They all offer less resistance to the passage of warp than twine eyes, and wear better; but they usually take up more room.

The following amongst other materials have been used to make healds: Worsted, linen, silk, cotton, iron, and steel; but cotton, steel, and worsted are now chiefly employed. Down to a comparatively recent period worsted was the principal heald twine used in the cotton and silk industries, but cotton healds have entirely superseded worsted in the former, and to a large extent in the latter, because they are cheaper, will work as well as and last longer than worsted for all but exceptional purposes.

Heald-making is now a special business and is usually conducted in separate establishments. During the latter half of the nineteenth century healds were greatly improved by the introduction of automatic knitting machinery, and by the skill and care bestowed upon sizing, varnishing, and drying them; but as this branch is outside the scope of the present work, the machinery and processes requisite for its successful accomplishment will not be dealt with. Too much importance cannot, however, be attached to sizing and varnishing, for defective work at this stage produces detrimental effects in the loom, such as swollen and

twisted twine, eyes closed or sideways to the warp instead of open and facing it, roughness, lumps of size and varnish in the eyes, rigidity, stickiness, and lack of lasting properties. Healds should be flexible, smooth, capable of resisting friction and strain, and readily adjustable to any reed or pattern.

The twine of which healds are made should vary in thickness and strength to suit the warp it has to actuate. If a given twine is suitable for a fabric containing few threads per inch, it would be crowded upon the shafts if the number of loops were largely increased, and additional friction would be put upon the warp; also, twine strong enough to control fine warp would be unable to resist the strain put upon a coarse warp.

A rule that would enable a manufacturer to select heald twine with an approximation to mathematical accuracy is much to be desired, but unfortunately no such rule is available, chiefly owing to a lack of definite information respecting the effect spinning and doubling twist has in reducing the diameter of a thread, and that of sizing and varnishing has in increasing it. Several attempts have been made to proportion heald twine, but from various causes they have been rejected, and the matter is still left to the experience of the mill manager or the knitter.

The following table of yarns will serve as a guide in the selection of counts suitable for different reeds; but although the higher foldings for any reed will make the strongest healds, they are the most costly :—

[TABLE

Reed, viz. number of dents on 2″.		Suitable Counts from which a Selection can be made.				
30	36	20/40	24/50	28/60	...	...
38	44	18/40	20/50	24/60	...	...
46	52	15/40	18/50	21/60	...	..
54	60	12/40	15/50	18/60	...	..
62	66	12/40	12/50	15/60	...	...
68	72	...	9/50	12/60	16/70	...
74	80	...	...	9/60	12/70	...
82	100	...	...	...	9/70	12/80

With ordinary knitting each heald occupies a fixed position upon a shaft, and a change of pattern often necessitates a change of healds. This is both inconvenient and expensive, and adjustable twine healds have been introduced in order to render such changes unnecessary. The Miller loose heald is made from two pieces of twine and is similar to the usual eyed heald, except that above the upper and beneath the lower shaft each twine is double knotted; the first knot completes the loop, the second forms an eye through which a band is passed to prevent the healds on one shaft from becoming crossed. But the band permits each heald to slide freely into its proper place. Loose plaited healds are also used. They are made in one continuous length by plaiting, say, six strands of yarn together for a fixed distance above and below the eyes, and then twisting two sets of three strands to form the eyes and the lengths between the eyes and the ridge bands; similar plaitings, together with short lengths of twisted twine, occur above and below the shafts. The healds are folded and bands are inserted in the top and bottom loops to define the relative position of each heald. These healds are superior to others because at the eye they are no thicker than elsewhere, whereas knotted eyes are

apt to rub and break adjacent warp threads as they rise and fall. A few years ago metallic clips were employed to form eyes on twine healds, but they were not successful; experience proved them to be more costly without being more durable than ordinary healds. Other healds are made

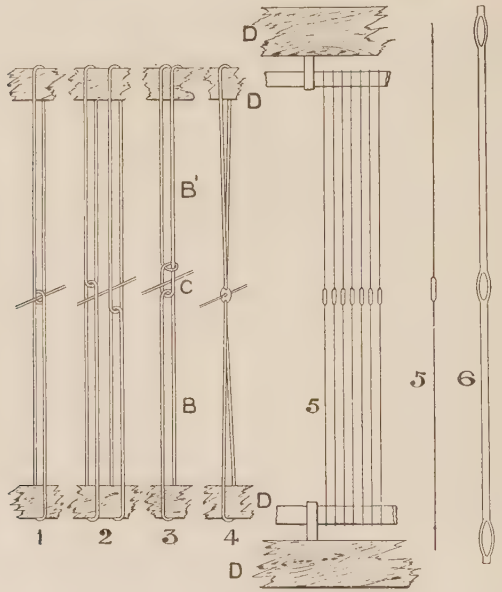


FIG. 3.

of twisted wire, a small loop being left in the centre for the warp to pass through, and longer ones at each end for the reception of shafts, upon which they are loosely placed (see 5, Fig. 3). Instead of the top and bottom loops, some are bent over and under thin metal shafts to form hooks, as then they are more readily attached and removed. Others again are made of reed wire, each strip of which has an eye punched at the centre for a thread, and slots formed near

the top and bottom to receive thin shafts (see 6, Fig. 3). When used for silk the eyes of these healds are sideways to the reed, but when used for cotton, the wire, at the eye, is slightly bent to the right and left in order that the eye may face the reed. It is claimed that wire healds last longer than twine healds, that they are perfectly smooth and equally suitable for close and open textures. Being loose upon the shafts they are self-adjusting, for each heald will readily move into its appointed position by the pull of the warp. By sliding a few healds on or off a shaft the required number can be obtained for any draft.

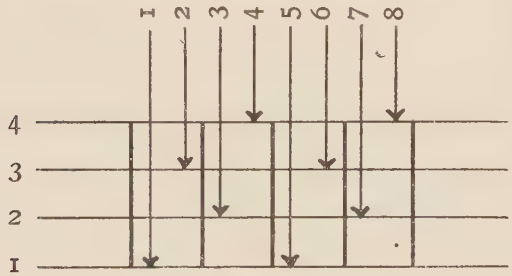


Fig. 4.

The disadvantages of wire healds are, that if one breaks, there is a tendency to cut contiguous warp threads, and being less flexible than twine, more difficulty is experienced in repairing broken warp. Many wire healds also occupy more space in the loom than those made from twine. In some manufacturing centres wire healds are largely used, but in others they are rarely met with.

The positions of healds upon the shafts must correspond with the order in which warp is to be drawn through them, and with the reed to be used. See Part XVII. For example, if a reed contains 100 warp threads per inch, the shafts in a set must contain 100 healds in one lineal inch,

but they may be equally or unequally spaced upon the shafts, therefore it will also be necessary to consider their distribution.

A reference to Fig. 4, which is a draft or plan of draw-

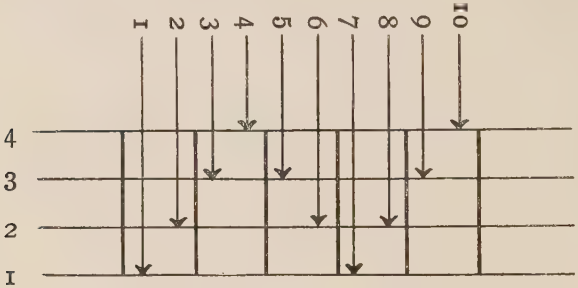


Fig. 5.

ing the warp through the healds, will make this clear. Each horizontal line represents a heald shaft; each thick vertical line a reed wire; each thin vertical line a warp thread; an arrow-head marks the position of a heald eye;

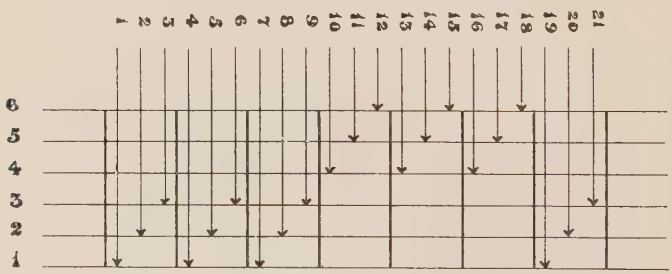


Fig. 6.

and the spaces between the thick lines show the scheme of drawing the warp into the reed.

In order to find how many threads a draft repeats upon, the position of every thread must be observed, and a place

found where the scheme recurs. Thus wherever consecutive threads from two places occupy similar positions, the repeat is obtained by counting from one point to the other.

In Fig. 4, four threads complete the pattern, because 1 and 5, 2 and 6, 3 and 7, 4 and 8 respectively occupy similar positions. In Figs. 5, 6, 7, and 8 the drafts are complete on 6, 18, 16, and 40 threads respectively.

The number of healds required for any shaft can be found by the following rule :—

$$\frac{\text{Dents per inch in the reed} \times \text{the inches of reed filled}}{\text{The number of dents filled by one pattern}} =$$

the number of patterns required :—The number of threads per pattern, on any shaft, multiplied by the number of patterns required, gives the healds for that shaft.

In the following examples a reed is assumed to contain 30 dents per inch, and to be filled for 24 inches, irrespective of selvage threads. In Fig. 4 four threads give one repeat, and they fill two dents; each shaft will therefore require $\frac{30 \times 24}{2} = 360$ repeats of the pattern on 24 inches; also, since there is only one thread on each shaft to a pattern, 360 healds per shaft.

In Fig. 5 six threads equal one repeat, and they occupy 3 dents in the reed, $\therefore \frac{30 \times 24}{3} = 240$ repeats. Here shafts 1 and 4 have each one thread to a pattern, but shafts 2 and 3 have each two threads to a pattern. $\therefore$

$$240 \times 1 = 240 \text{ healds on shafts 1 and 4.}$$
$$240 \times 2 = 480 \text{ healds on shafts 2 and 3.}$$

In Fig. 6 the warp threads are arranged in groups upon two sets of shafts, and in the case of all healds that occupy

fixed positions upon the shafts, it is desirable to obtain the rate and order of knitting as well as the number on a shaft.

The draft indicates three threads to each dent, and six dents to one repeat, $\therefore \frac{30 \times 24}{6} = 120$ repeats, and as there are three threads on each shaft to one repeat, $120 \times 3 = 360$ healds per shaft, but they are irregularly distributed.

The *rate* of knitting can be obtained in the following manner:—Since one dent of this reed equals $\frac{1}{30}$ of an inch, and 6 dents are used for each pattern, one pattern $= \frac{6}{30}$ of an inch; but as each shaft requires 3 healds knitting, and a space leaving equal to 3 more, it follows that 3 healds must only occupy $\frac{3}{30}$ of an inch, $\therefore$ 1 heald $= \frac{1}{30}$ of an each, and 30 is the rate of knitting. Or the rate of knitting may be found in this way :—

$$\frac{\text{The threads per inch in the reed}}{\text{The number of shafts in a group}} = \text{the rate.}$$

Thus, $\frac{30 \times 3}{3} = 30$, the rate.

The distribution or *order* of knitting is determined by the draft and the denting, thus :—3 knitted, 3 missed, for shafts 1, 2, and 3; and for shafts 4, 5, and 6, 3 are missed, 3 knitted. In practice the healds for all these shafts would be knitted alike, but then those on the three back shafts must be placed opposite the gaps in the first three.

Some drafts are irregular in both healds and reed and necessitate the making of several distinct calculations; as in the following examples :—

In Fig. 7 the threads from shafts 1, 2, 3, and 4 are reeded two in a dent, and those from shafts 5 to 12 are four

in a dent ; in all there are six dents to a repeat, $\therefore \frac{30 \times 24}{6}$ = 120 repeats. Shafts 5 to 12 have each one thread to a pattern, $\therefore 120 \times 1 = 120$ heals per shaft.

Shafts 1 to 4 have each two threads in a pattern, $\therefore 120 \times 2 = 240$ per shaft.

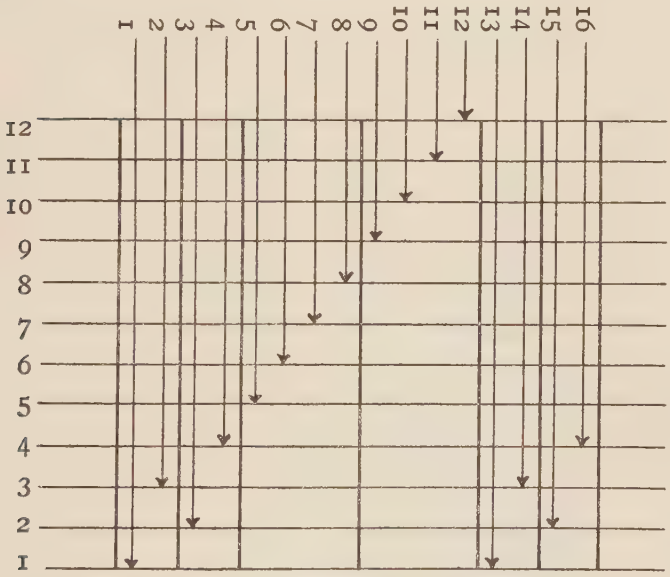


FIG. 7.

Calculations should be checked by finding the number of warp threads required to fill the reed, and comparing that number with the healds in a set ; unless both correspond, an error has been made, for every thread has a separate eye :—Thus 16 warp threads per pattern × 120 patterns = 1920 warp threads.

Shafts 5 to 12 each with 120 healds = $120 \times 8 = 960$
„ 1 to 4 „ 240 „ = $240 \times 4 = 960$
Total 1920

thus proving the preceding calculation to be correct.

The *rate* of knitting is as follows :—

Shafts 1 to 4 control threads which are two in a dent in the reed, or $30 \times 2 = 60$ per inch, and $60 \div 4$ shafts $= 15$, the rate of knitting. Also shafts 5 to 12 control threads which are four in a dent in the reed, or $30 \times 4 = 120$ per inch, and $120 \div 8$ shafts $= 15$, the rate of knitting.

The *order* is as follows :—Since the pattern occupies six dents and there is only one thread in two dents on any shaft, it follows that provision need only be made for three healds on six dents,

∴ Shafts 1 to 4, knit 1, miss 1, knit 1.
Shafts 5 to 12, miss 1, knit 1, miss 1.

In Fig. 8 the drafts in the healds and reed are both irregular; the threads from shaft 4 are reeded two in a dent, those from the remaining shafts three in a dent, and one repeat occupies 14 dents.

$$\therefore \frac{30 \times 24}{14} = 51\tfrac{3}{7} \text{ patterns,}$$

$\frac{3}{7}$ of 14 dents = 6 dents; these may be filled with selvage threads, and 51 patterns used.

Shafts.			SUMMARY.			Healds.
1, 2, 3	each has	1 thread	to a pattern	=	$51 \times 1 = 51 \times 3$	= 153
4	has	4 threads	„	=	51×4	= 204
5	„	3 „	„	=	51×3	= 153
6, 9	each has	6 „	„	=	$51 \times 6 = 306 \times 2$	= 612
7, 8	„	8 „	„	=	$51 \times 8 = 408 \times 2$	= 816
10	has	2 „	„	=	$51 \times 2 = 102$	= 102
					Total	2040

Proof.—Forty threads per pattern × 51 patterns = 2040 warp threads. In all cases provision must be made for selvage threads, either by knitting extra healds upon the shafts used for the body, or, if the selvage weave differs from the body weave, by adding separate shafts.

It has been shown that the number of dents per inch in a reed will give the *rate* of knitting; but it is often more expeditious, and equally accurate, to use a lower rate. It is advisable, however, that the lower rate shall be a measure of the number of dents per pattern, as $\frac{1}{2}$ or $\frac{1}{4}$. In the following example shafts 1, 2, 3 are knitted at half the reed rate, namely, 15 per inch, and the order for those shafts is, knit 1, miss 6. The order for shaft 4 is, knit 2, miss 10, at the rate of 30 per inch. This rate will place threads 1, 2, 39, 40, facing dents

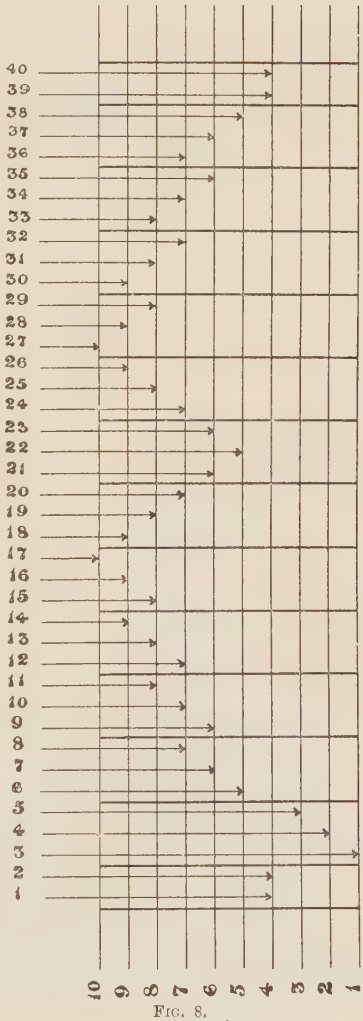


FIG. 8.

1, 2, 13, 14, respectively, instead of threads 1, 2, facing dent 1, and threads 39, 40, facing dent 14. But a rate of 60 per inch would overcrowd the twine on the shafts.

The warp is drawn one thread in an eye.

For shaft 5, miss 1, knit 1, miss 1, knit 1, miss 2, knit 1, at the rate of 15 per inch.

„ 6, miss 2, knit 2, miss 3, knit 2, miss 2, knit 2, miss 1, at the rate of 30 per inch.

„ 7, miss 2, knit 3, miss 1, knit 1, miss 1, knit 1, miss 1, knit 3, miss 1, at the rate of 30 per inch.

„ 8, miss 3, knit 4, miss 1, knit 4, miss 2, at the rate of 30 per inch.

„ 9, miss 4, knit 3, miss 1, knit 3, miss 3, at the rate of 30 per inch.

„ 10, miss 2, knit 1, miss 1, knit 1, miss 2, at the rate of 15 per inch.

Heald-setting is resorted to when a set of healds, knitted for a given reed, is used with a coarser reed. In such an event some healds must be left empty; but they should be equally distributed on the shafts.

The order of setting can be obtained by the aid of the following formula:—

$$\frac{\text{The reed to be used}}{\text{The reed for which the healds are knitted} - \text{the reed to be used.}}$$

Example.—Let it be assumed that healds suitable for a reed with 39 dents per inch are to be used with a reed containing only 26 dents per inch, then there will be two full courses of the healds to one empty course from end to end.

$$\therefore \frac{26}{39-26} = \frac{2}{1}.$$

Or, set above the reed to be used, and in the form of a fraction, the difference between the count of the healds and the reed. Reduce it to its lowest term, and the denomi-

nator will show the number of courses to be drawn, the numerator those to be missed.

Example.—The healds are 78 count, the reed to be used is 52 count; therefore, $78 - 52 = \frac{26}{52} = \frac{1}{2}$.

If healds suitable for a reed with 38 dents per inch are used with a reed containing 32 dents per inch, 16 courses will be filled to 3 missed.

$$\therefore \frac{32}{38 - 32} = \frac{16}{3}.$$

Or the healds are 76 count, and the reed to be used is 64 count; therefore, $76 - 64 = \frac{12}{64} = \frac{3}{16}$.

In this case probably the best result will be obtained if the warp is drawn as follows :—

	5 courses filled	and	1 missed.
	5 ,,	,,	1 ,,
	6 ,,	,,	1 ,,
Total	16 filled		3 missed.

PART III

SHEDDING OR DIVIDING THE WARP

Two kinds of sheds are formed which are respectively known as "closed" and "open." In the former, the mechanism employed places all the warp threads level after the insertion of each pick of weft. In the latter the warp is only moved when the pattern necessitates a change of position.

There are two methods of producing closed shedding; first, by giving motion only to threads that are to form the upper line. Under this condition the warp is level on the bottom line; hence, in order to form a top shed, it is necessary to move some threads through a space equal to twice the depth of a shed, once up and once down, before a

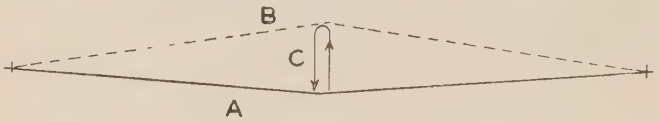


FIG. 9.

fresh selection can be made. A shed of this kind is known as a stationary bottom with a rising and falling top. See Fig. 9, where A represents the bottom line of warp, B the rising and falling line, and C an arrow showing the space passed through. The foregoing method is defective in the following respects:—1st, it takes a long time to make a change, and is unsuitable for high speeds; and 2nd,

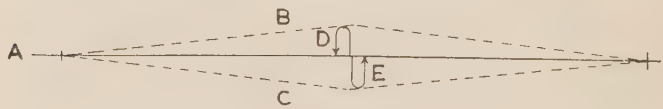


FIG. 10.

great and unequal strain is put upon the warp by moving it through an excessive space. Certain tappets, all single-lift dobbies and Jacquard machines act in the above manner.

The second method of forming a closed shed consists in imparting an upward movement to those threads which are to form the top line, and a downward movement to those threads which are to form the bottom line; then, after

inserting a weft thread, both lines are restored to the closed position, which is often half-way between the highest and lowest points of an open shed. Fig. 10 represents a centre shed; A is the closed warp line, B and C are respectively the upper and lower lines of an open shed, D and E are arrows which show the movement of each thread to equal the depth of shed—namely, half the distance in an upward and half in a downward direction.

If compared with a stationary bottom shed, it will be found superior in the following respects:—1st, although every thread is moved to form every shed, yet the strain is less; 2nd, the time occupied in opening a shed is approximately reduced by half, for the distance travelled by a thread is as 1 : 2. 3rd, a rising thread is partially balanced by a falling one; but an unsteady movement is caused by the warp being in constant motion. In this respect it is inferior to a stationary bottom shed.

Many Woodcroft tappets, the Jamieson, the oscillating, and certain others, together with all centre shed dobbies and Jacquards, act in this manner, but although closed shedding is best adapted for the manufacture of certain types of fabrics, open shedding has the widest range of application.

In open shedding the bulk of the warp forms two stationary lines, and changes are made by carrying threads from one fixed line to the other. The ascending and descending threads move simultaneously, and form a shed in the minimum of time, with comparatively little strain upon the warp, because there is no unnecessary movement given to it, and the falling threads help to lift the rising ones.

In Fig. 11 A and B are the stationary lines of warp, C and D are arrows which show the movement of falling

and rising warp to equal the distance between A and B.

This method, however, is troublesome to a weaver in proportion to the number of shafts in use; because the two fixed shed lines make it more difficult to repair broken threads than where all the warp forms a single line. Some simple and effective apparatus should be added to all open shedding motions to place the healds in one plane whenever repairs become necessary, and replace them in their original positions before restarting the loom. By one plan the top shaft A, Fig. 51, is mounted in slotted brackets but

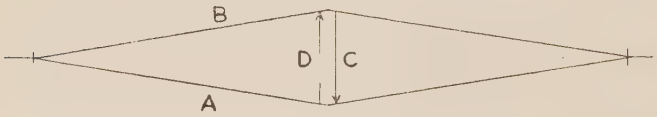


FIG. 11.

rests upon two cams. By operating a lever the cams lower the shaft sufficiently to slacken the straps 1, 2, 3, 4, 5, and bring the healds level; then, before recommencing to weave, the shaft A is restored to its normal position. Other plans are illustrated in Figs. 73, 74. Where the number of heald shafts is great, the warp in the back shafts is strained and broken more than that in the front shafts; and means have been devised for reducing such strain during beating-up. Open shedding is obtained by the use of ordinary tappets, the Hattersley, and the Knowles dobbies, and a few Jacquards.

Many of the best-known shedding motions form a shed which is compounded for the closed and open principles, and may be defined as semi-open. In it the stationary bottom line is retained, but threads from the top line either

pass to the bottom at one movement, or are arrested midway and again carried to the top.

Such a shed can be formed as expeditiously as an open one, for the upward movement begins and ends with the downward through movement, and the arrested downward movement is converted into an upward one immediately the falling threads are in the same plane as the rising ones; they all reach the top together, but the strain upon them is not so equally distributed as in an open shed. Double-lift Jacquards and certain dobbies form semi-open sheds.

In Fig. 12, A is the stationary bottom, B the top line,

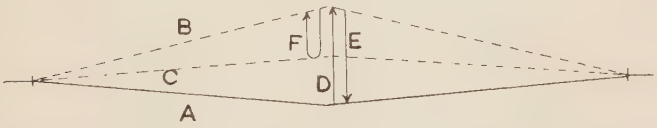


FIG. 12.

C the point where downward movement ceases in threads that are to form part of the top line for the succeeding pick, D and E are arrows showing the movements of through threads, and F that of threads which are to lift for the following pick.

On p. 3 it is stated that healds, under certain conditions, are capable of giving the most perfect form of shedding. It remains to consider what those conditions are, and in what respects healds fail to meet all requirements. Healds can only be employed when a large number of warp threads move up and down in the same sequence. A reference to any of the heald calculations, pp. 13 to 18, will show how many threads must move with each shaft. If that number is reduced and the same warp retained, the number of shafts must be increased in proportion, but a point is soon reached

beyond which it is impossible to go, owing to the great space that separates the front and back shafts when in a loom.

In the cotton trade this limit is reached at from 20 to 24 shafts, but in the worsted trade a larger number is employed. In any event, only a few warp threads can be moved independently. This is the weakest feature of healds for general work ; they are only suitable for patterns which are of a more or less set character, and in which curved lines are absent or only present to a limited extent. Where flowing lines and elaborate geometrical or floral effects are required a Jacquard machine must be employed.

Healds are placed at right angles to the warp threads, and must be so connected to the shedding motion that a vertical pull will be exerted upon them, for a lateral movement, however slight, is detrimental to good weaving. They must also be moved at a varying velocity to correspond, as far as possible, with the tension upon the warp. Although this strain is not equal in all systems of shedding, still it rapidly increases as the warp approaches the upper and lower lines, hence to minimise strain the healds should move slower as the work to be done increases.

The parts generally used for heald-shedding are known as tappets, barrel motions, and dobbies. The two former are, as a rule, best adapted for the production of patterns with not more than 16 weft threads to a repeat.

In respect to length of pattern dobbies are only limited by the space provided for cards or lags ; they are frequently used for more than 8 shafts, and generally so for more than 12. Still, if a tappet or a barrel motion can be conveniently employed, the best results will follow, for they are the simplest of all shedding motions ; they are certain in action, and capable of lifting a heavy weight with less wear and tear than other appliances. They

can be made to move healds at any speed, and leave them stationary for any length of time. No shedding motion will put less strain upon the warp, consume less power, give a greater output, or cause fewer defects in a finished fabric. These are points that tell greatly in favour of tappets.

Tappets

"Tappet, cam, and wiper are names given indiscriminately to those irregular pieces of mechanism to which a rotary motion is given for the purpose of producing, by sliding contact, reciprocating motions in rods and levers. When the rod is to receive a series of lifts, with intervals of rest, the piece is generally called a tappet; but if motion is continuous, the terms cam and wiper are used."

Tappets are made in great variety, and are fixed on different parts of a loom—namely, under and over the heald-shaft centres; under and over one end of the heald shafts, and outside the end framing. Position is, however, often a question of convenience; but the leading ideas which govern it are economy of floor space, handiness of parts, and the best manner of performing the work to be done. For 2, 3, 4, and 5 shafts tappets are often placed under the warp, but for more than 5 shafts, they are generally placed at one end of a loom. They act in different ways; the simplest in construction have merely a rotary motion, but some have a compound movement, partly rotary, partly oscillating. Tappets differ also in principle—some are negative or conditional, others are positive. A negative tappet can only either pull the healds down, or lift them; in all such motions additional mechanism must be added to impart the opposite movement, but a positive tappet controls the healds in both directions without the aid of secondary appliances.

Figs. 13, 14, 18, 26, 27, and 33 show tappets with their requisite connections in each of the positions above named.

In Fig. 13, A, A′ are two plates of a negative tappet, both fixed on the tappet shaft beneath the centre of the healds C, C′. Two treadles, D, D′, move on a fulcrum pin E, and each carries an antifriction roller F, F′, upon which the plates act as they rotate; G, G′ are straps and cords which connect the treadles D, D′ to the bottom heald shafts. Cords and straps, H, H′, connected to the upper heald shafts are secured respectively to the peripheries of two rollers K, K′, which may be either fast or loose upon a shaft B; if fast the shaft works freely in bearings. When these tappets are in motion the treadles are alternately depressed, and the under connections impart a similar downward movement to the healds; but as the tappets are incapable of lifting either the treadles or the healds, the upward motion is entirely due to the top connections and pulleys. Thus, as one heald shaft is depressed by a treadle, the strap H is unwound from the roller K, and H′ is wound upon K′ or *vice versa*; therefore a sinking heald is made to lift its fellow, and the negative action of a tappet is converted into a positive one by the rollers and straps. When these tappets are placed above the healds their positive action is to lift the shafts, and rollers, springs, or weights are fixed below to reverse the direction of motion (see Fig. 27).

Various defects are common in tappet-shedding, such as over, under, and unequal shedding, and that in which the healds move as the shuttle passes through the warp, and in which they move unsteadily. Of these the most frequent is over-shedding, or making the division in the warp unnecessarily wide; this strains and breaks the threads. In under-shedding the warp is not sufficiently divided to allow the shuttle to pass through, therefore it

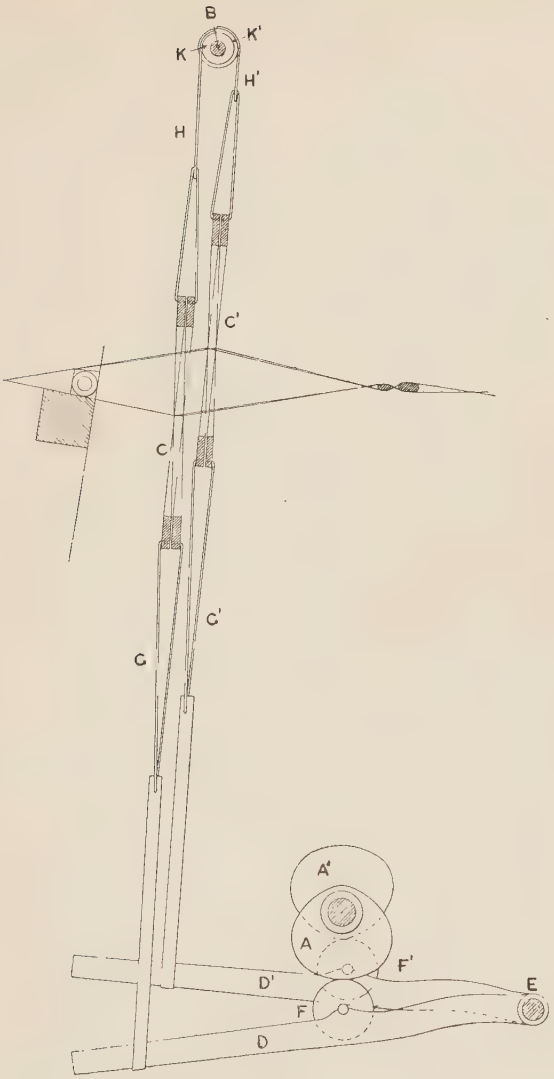


FIG. 13.

moves over threads it should move under, or breaks them, and a stronger pick is required. Unequal shedding is caused by lifting one end of a shaft more than the other, also by cording the shafts so that they do not lift or sink the warp to one level where the shuttle passes through it. When shedding is mistimed, the warp is opened or closed without due regard to the slay's motion; the cloth is then faulty by reason of the shuttle passing between the wrong threads and breaking them. If the dwell or pause of a tappet is unsuited to the fabric, the last-named defects will also be caused, and when a tappet is faulty in form, it imparts a harsh movement to the healds. In the majority of cotton looms, contact between the tappet and the treadle bowl is only maintained for about half a revolution of the tappet, hence as the tappet turns into its treading position a blow of considerable severity is inflicted upon the bowl, from whence vibration is transmitted to the healds and the warp. All these defects put unnecessary strain upon the warp, but most of them can be avoided by care on the overlooker's part.

As the quality and quantity of work produced by a loom are influenced by the form of the tappet employed, care should be taken to construct it in such a way that the greatest length and the best quality of cloth will be obtained in a given time.

Before commencing to design a tappet, the following items must be carefully considered:—

1. The pattern to be produced in the fabric—A, the number of picks of weft to one repeat; B, the order of lifting and depressing the healds.
2. The size of a tappet—A, the space through which the healds must move to give room for a shuttle

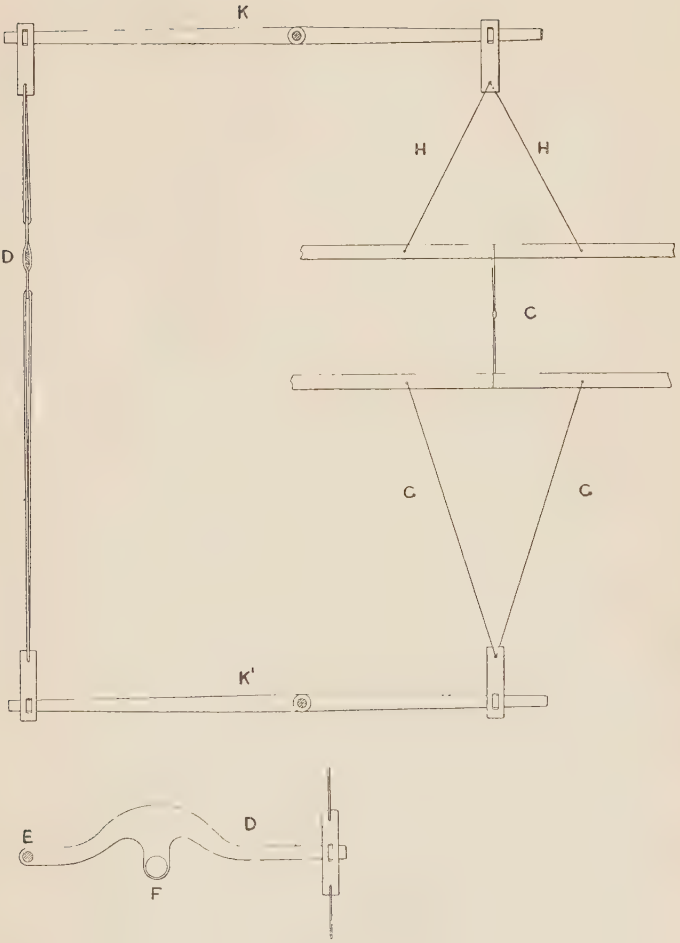


Fig. 14.

to pass through a shed; B, the difference in size between the small and large surfaces of a tappet to impart the necessary movement to the healds; C, the distance from the centre to the smallest part of the tappet surface.

3. The nature of the movement to be imparted to the healds.
4. The time during which the healds are to remain stationary.
5. The diameter of the treadle bowl.

A plan showing how the healds must rise and fall for one repeat of a pattern is given to a tappet-maker. This is known as the tie-up or lifting plan; the marks upon it may represent either rising or sinking healds, but it is usual to state which is intended.

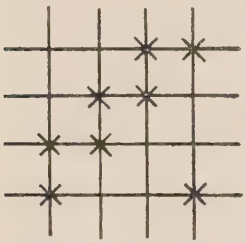


FIG. 15.

Figs. 15 and 16 show different ways of making a tie-up; in the first, each vertical line represents a tappet treadle, and each horizontal line a heald shaft.

By reading up a vertical line, the crosses at the points of intersection show which healds are to be moved for one pick; and by reading across a horizontal line, the order of lifting one shaft for a repeat of the pattern is obtained. As one tappet plate acts only on one shaft, horizontal readings must be taken when designing a tappet, and the number of vertical lines gives the number of picks to a repeat.

The only difference between the first and second figures is that, in the latter, the *spaces between* the vertical and horizontal lines respectively represent treadles and shafts instead of the lines themselves.

The first of the five points named is thus seen to be a simple matter—namely, that of obtaining the number of picks to a repeat, and the order of lifting the healds.

The next point requires more attention. It is necessary to ascertain the depth of the shuttle to be used when measured along its front edge; the distance of its front edge, at the time it enters a shed, from the last pick of weft in the fabric, and the distance from the last pick to the heald shaft. The arrangement of levers, and the position of the bowl upon the tappet treadle must also be defined. In Fig. 17 all the above-named parts are shown in working positions. Assume A, the shuttle, to be 1·125″ deep; B, the last pick, or the cloth fell, to front of shuttle, 3·375″; C, the cloth fell to front heald shaft, 10″; and that from the cloth fell to the back heald shaft 12″; D, the treadle fulcrum to the bowl centre, 11·25″; D, E, the point of connection with the front heald to treadle fulcrum, 19·25″, and to the back heald 17·25″. Then 3·375 : 10 : : 1·125 : 3·33″, the lift of the front heald; and 19·25 : 11·25 : : 3·33 : 1·94″, which equals the lift of the tappet for that heald. Also, 3·375 : 12 : : 1·125 : 4″, the lift of the back heald; and 17·25 : 11·25 : : 4 : 2·609″, which equals the lift of the tappet for the back heald.

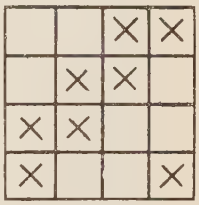


FIG. 16.

When a tappet is placed at the end of a loom, additional levers are required, as seen in Figs. 14, 18, and 19.

In Fig. 18 A is a shuttle 1·125″ deep at its front edge; B, the cloth fell to front of shuttle, 2·75″; C, the cloth fell to heald shaft, 8·5″; D, the top lever fulcrum to heald strap, 5·75″; E, the top lever fulcrum to treadle connection, 6·5″; F, the treadle fulcrum to centre of bowl, 22·5″; G, the

treadle fulcrum to connection with top lever, 30″, ∴ 2·75 : 3·5 : : 1·125 : 3·477″ = the lift of heald; and 5·75 : 6·5 : : 3·477 : 3·93″ = the fall of top lever at the treadle connection; also 30 : 22·5 : : 3·93 : 2·947″ = the required lift of the tappet.

Fig. 19 is an arrangement for positive shedding, but the method of obtaining the lift of a tappet is precisely similar to that in the last example: A is the shuttle which is 1·25″ deep at the front; B, the cloth fell to front of shuttle, 4″; C, the fell to heald shaft, 8″; D, the top lever fulcrum to heald strap, 19″; E, the top lever fulcrum to treadle connection, 20·5″; F, the treadle fulcrum to centre of bowl, 11″; G, the treadle fulcrum to connection with top lever, 26″; H, the bottom levers, which correspond with top ones. See Fig. 14, which shows the up and down movement of a heald shaft to be equal.

To find the tappet lift—

4 : 8 : : 1·25 : 2·5″ = the lift of the heald.

19 : 20·5 : : 2·5 : 2·7″ = the fall of the top lever at the point where it is connected with the tappet treadle.

26 : 11 : : 2·7 : 1·1″ = the lift of the tappet.

In order to prevent unnecessary breakage of the warp, it is desirable that a shed shall be as small as the nature of the work to be done will allow. This matter is of great importance, because the strain upon a warp increases approximately as the square of the space passed through. If, for example, from a closed shed the warp is lifted 2″, the strain is represented by 4, but if lifted 3″ or 4″, the relative strains are as 9 and 16 respectively, hence doubling the size of a shed increases the strain fourfold.

The following simple practical test may be of use in demonstrating the above. Assume the distance from the

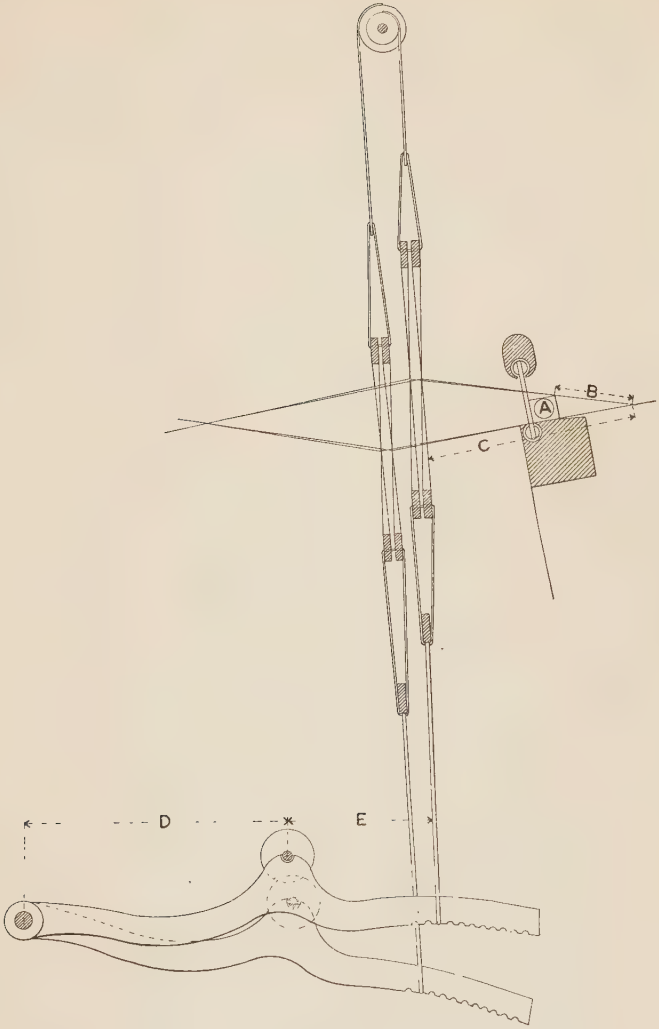


Fig. 17.

cloth fell A, Fig. 20, to the back rest B, to equal 35″, and from the fell to the healds C, 10″. Then let the edge of a table represent the back rest B; and take a piece of twine, say $1\frac{1}{2}$ yards long, tie a weight to one end, allow it to hang over at point B; fasten the other end by a drawing pin at point A, 35″ from B. Mark the horizontal twine at B; place a rule vertical at 10″ from A, and lift the twine 2″ at C; make a second mark upon the twine at B. Continue to lift the twine at C to the fourth inch on the rule, and make a third mark upon it at B. Measure the spaces between the first and second, and second and third marks, and it will be found that the second space is approximately four times as wide as the first. In weaving, the warp is pulled from the beam in that proportion. Vibrating bars have been neglected on the assumption that both looms are similarly constructed, and that both bars if used will act in the same manner.

The distance between a tappet centre and the smallest part of its surface varies according to its position in the loom and the number of picks to the round. Plain tappets placed under the shafts average $1\frac{1}{4}$″. Tappets for 3, 4, and 5 picks to the round similarly placed vary from 2″ to $2\frac{1}{2}$″. If placed at the loom end, for 3, 4, or 5 picks, they vary from $2\frac{1}{2}$″ to 3″. Above five to the round, plates are increased considerably in size; a Woodcroft for 3 to 16 picks being 17″ in diameter, and larger still for higher picks.

The movement given to healds should be regulated to put the least strain upon the warp. Three methods are available for the accomplishment of this object, and when combined the best results will follow. They are, first, that the pause shall be as short as practicable, in order to allow the maximum time for forming a shed. Second, that velocity in the healds shall be in inverse proportion to the

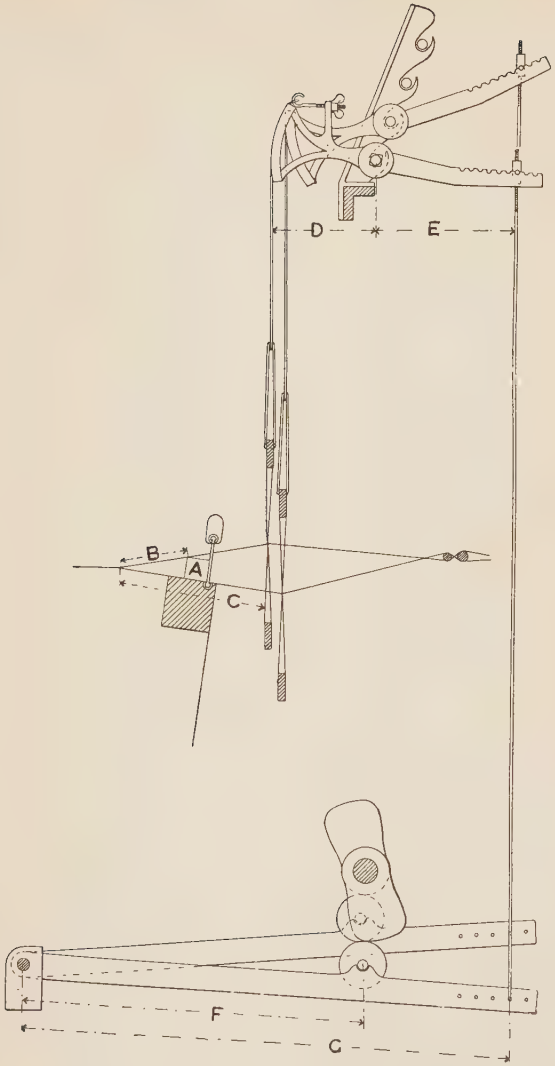


Fig. 18.

strain upon the warp. This requires a quick movement when the healds are midway between the extremities of their journey, and a gradual reduction in speed as the upper and lower shed lines are approached. Third, that movement in a heald shall only take place when absolutely

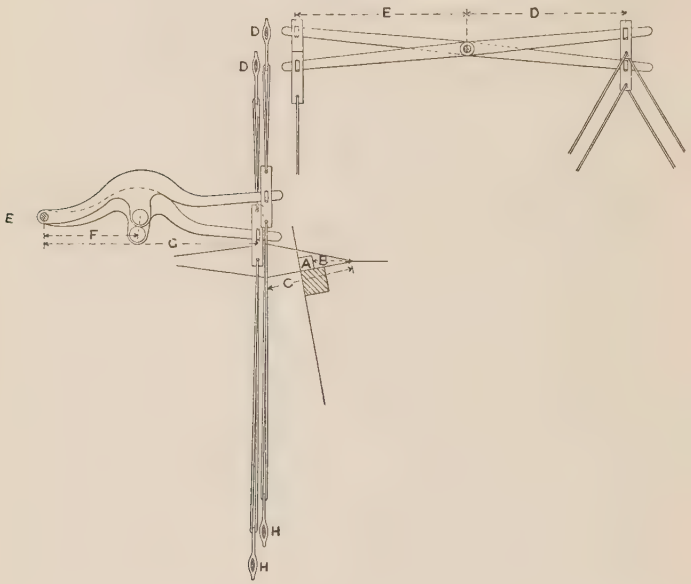


FIG. 19.

necessary. By adopting these courses jerks are avoided, and an approximately equal strain is maintained throughout the movement.

Tappets should be so made that healds will be stationary while a shuttle is in the warp; this stationary period is known as pause or dwell, but its duration must vary to suit the fabric to be made.

In certain textures the warp threads may run, more or less, in pairs without the pieces being considered defective; they are then said to be reed marked, or without cover, and the tappets employed may be made with just sufficient pause to allow a shuttle to move through the warp, and that varies from $\frac{1}{4}$ to $\frac{3}{8}$ of a pick. But in *covered* cloths all the threads are equidistant; for such, and also for heavy fabrics, a pause of $\frac{1}{2}$, $\frac{2}{5}$, or $\frac{1}{3}$ of a pick should be given.

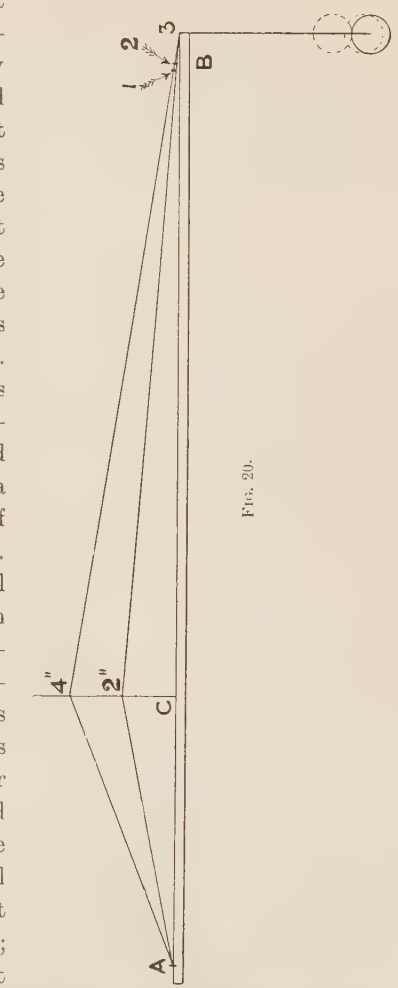


Fig. 20.

The correct dwell for a tappet has been defined as follows:— Divide the circle described by the cranks into 12 equal parts, as in Fig. 21. If number 1 represents the reed in contact with the cloth, the shuttle will begin to move at 4; at 5 it will enter the warp; at 9 it will leave it; at 10 it will be stationary in the opposite shuttle-box. From

9 to 5 equals $\frac{2}{3}$ of a revolution, this is therefore the maximum time to allow for changing the positions of the healds; and from 5 to 9, which is $\frac{1}{3}$ of a revolution, all the healds must be stationary.

A dwell of $\frac{2}{3}$ of a pick has been advocated for heavy and well-covered fabrics, but this appears unnecessarily long, as any reduction in the time for moving the healds increases the strain upon the warp proportionately. Only a small number of the tappets in use have a dwell exceeding $\frac{1}{2}$ a pick. The majority of those fitted upon Lancashire looms for weaving well-covered fabrics have only $\frac{1}{3}$ of a pick for dwell; cover can be obtained by other means. See Part XXIII.

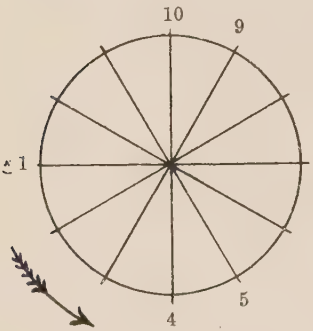


FIG. 21.

The last point refers to the treadle bowl, which is employed to reduce friction at the point of contact with the tappet. Generally speaking, a large roller gives a steadier motion than a small one, but the incline on the tappet surface may thereby be rendered too steep for good running. The diameters in common use vary from $1\frac{3}{4}''$ to $3\frac{1}{2}''$, the smaller ones being used with tappets having the greatest number of picks to a repeat. A tappet must be shaped to overcome the effect an antifriction roller has upon the motion of healds, or they will rise and fall at other times and speeds than those intended.

A tappet has an irregular surface, but a *point* could be made to follow its most minute variations. A point is, however, impossible, and an antifriction roller is used,

whose surface, under certain conditions, is capable of touching two parts of the tappet surface at one time (see Fig. 26).

Whatever space there may be between the points so touched is lost to the pause of the healds and one will begin to rise or fall before another. The only plan by which this defect can be overcome is to make the *roller*

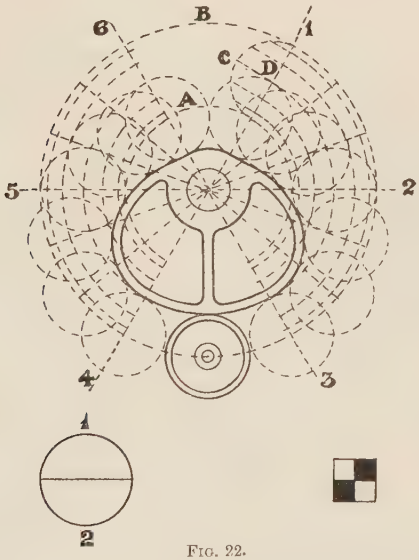


FIG. 22.

centre move as the healds are required to move, and to do this either the roller diameter must be reduced or the distance from the centre of the tappet to its surface must be increased. A tappet constructed for one size of roller will never work as satisfactorily with a roller of other dimensions.

Figs. 22, 23, 24, 25, and 28 show the methods to be

adopted when constructing tappets for different weaves; of these 22, 23, 24, and 25 are negative, or conditional, tappets.

Fig. 22 is for plain cloth. Fig. 23 is for a three-thread twill, one down, two up. Figs. 24 and 25 are for four-thread twills, one down and three up, and two up and two down respectively for each pick. Fig. 28 is a positive tappet for weaving the 6-picked pattern which accompanies it.

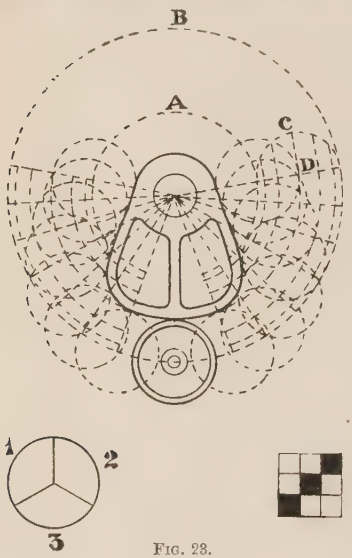


FIG. 23.

Assume the plain cloth tappet to be $1\frac{1}{4}''$ from its centre to the smallest surface, to have a lift of $3''$, a dwell of $\frac{1}{3}$ of a pick, and a treadle bowl $3''$ in diameter. To draw such a tappet, describe circle A, Fig. 22, equal in radius to the distance between the tappet centre and the centre of the treadle bowl when that bowl is touching the smallest part of the tappet. This $= 1\frac{1}{4}''+$ the radius of bowl $1\frac{1}{2}'' = 2\frac{3}{4}''$; add to that the lift of the tappet $3'' = 2\frac{3}{4}''+3'' = 5\frac{3}{4}''$, and describe a second circle B. When in action the treadle bowl constantly works on or between these lines. Since the pattern has 2 picks to a repeat, divide the circles, by a line 1, 4, into two equal parts. Subdivide each space into three equal parts, and draw the radial lines, 2, 5, 3, 6. The space 1, 3 equals $\frac{2}{3}$ of a pick, and is to be used for moving a shaft for the first pick. The space 3, 4 equals $\frac{1}{3}$ of a

pick, which is allowed for dwell. The space 4, 6 is to be used for moving the same shaft for the second pick, and 6, 1 is for dwell. Divide the spaces 1, 3 for the first, and 4, 6 for the second picks, into any number of equal parts by radial lines, say 6 each. Upon one of the radial lines describe a semicircle C, whose diameter shall equal the space separating the circles A, B, and touch both; divide the periphery of C into a number of equal parts corresponding to those in divisions 1, 3 and 4, 6 —namely 6. From each point of intersection on the periphery of C drop a line D perpendicular to its chord; the latter will then be unequally divided for the purpose of imparting a variable velocity to a heald shaft. Through each intersection on the chord describe a circle concentric with A, B. Let each point, where a radial line is cut by a curved one, represent the centre of the treadle bowl at one part of the lift; from those points, beginning on the inner circle A, and taking the others in rotation, describe circles equal in diameter to the treadle bowl, and the construction lines will be completed.

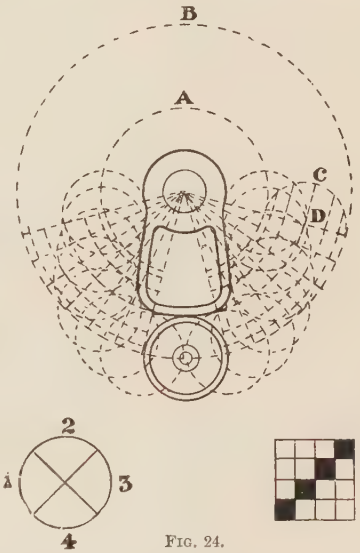


FIG. 24.

To find the shape of the tappet, trace a line touching the periphery of each bowl circle, and where the heald is

to be stationary, describe an arc from the tappet centre. What remains to be done is to show the thickness of the metal in a finished tappet, as in Figs. 22, 23, 24, and 25, and to suitably arrange the plates. For plain cloth two plates are needed, but taking the same point on the surface of each, the second plate must be turned through an angle of 180 degrees, and made fast by the side of number

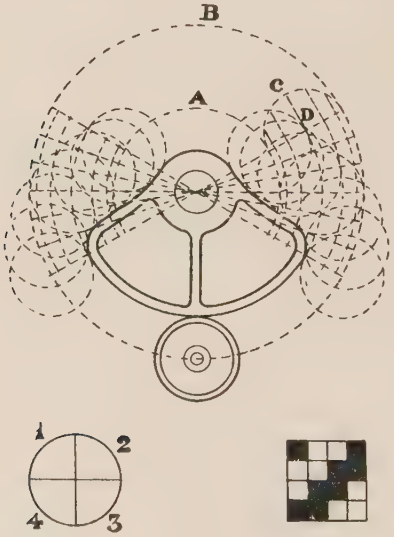


Fig. 25.

one. In Fig. 23 similar points on three plates must be placed at angles of 120 degrees to each other. In Figs. 24, 25 similar parts of four plates must be secured at angles of 90 degrees, and in Fig. 28 similar parts of six plates must be secured at angles of 60 degrees.

In order to reduce the strain upon delicate yarns during beating-up, the tappet shown in Fig. 25 would have a

slight inward curve on its surface, where the bowl is shown in solid lines, and a slight elevation exactly opposite the depression, for these reduce the size of a shed at the moment of beating-up.

Some tappets are split in the centre and provided with flanged bosses to facilitate attachment to, or removal from, a loom, and in places where changes are of frequent occurrence there is much to recommend the practice.

A tappet treadle, by swinging on its fulcrum pin, causes the friction bowl continually to change its place of contact relatively to the tappet centre; but the movement required is a rise and fall in a straight line. Hence, to approximate to the best motion, the centres of the treadle fulcrum and bowl should be in the same horizontal plane at half the lift; and the bowl and tappet centres in the same vertical plane, or the treadle will partially counteract the curved surfaces of the plates. Many looms are so constructed that the above-named adjustments cannot be made; in such cases the parts should be fixed to give a treadle, at its point of connection with the heald shaft, an equal swing in both directions from half the tappet lift. Contact between the treadle bowl and the tappet must be maintained, or the heald will have a jerky movement.

In order to place the warp level where a shuttle enters it, a back shaft must rise higher and sink lower than a front one; but if the treadle fulcrum pin is at the back of the loom as in Figs. 13 and 17, this cannot be accomplished with uniform tappet plates, for the connecting point with the back shaft is nearer the treadle fulcrum than that of the front shaft, hence the movement of a back shaft would be less instead of greater; it is usual to give an increased lift to a back plate of from $\frac{1}{8}''$ to $\frac{1}{4}''$, but the exact amount can be determined by calculation, as shown on p. 31.

If a treadle fulcrum is at the front of a loom, the back shaft connection is farther from the fulcrum pin than that of the front shaft, for which reason all plates may be of one size, and the difference in leverage will give a difference in lift.

If the stepped rollers called cones, see K, K′, Fig. 13, do not wind on or off exactly as much strap as the tappet treadle gives out or takes up, the straps will not be kept at a uniform tension. Suitable dimensions for the rollers may be found as follows :—

The correct lift of the back shaft : the correct lift of the front shaft : : the diameter of the largest roller : that of the smallest one. Thus, assuming the lift of the back shaft to be 4″, that of the front shaft 3·33″, and the large roller to have a diameter of 2″ :—4 : 3·33 : : 2 : 1·665″, the diameter of the small roller.

Jamieson's Tappet

A negative tappet, known as Jamieson's, is placed under the healds with its axis B′, Fig. 26, at right angles to and in the same horizontal plane as the bottom shaft A. A short shaft B carries a large bevel C, which engages with one of two small bevel pinions E, E′, that are fast upon the shaft A ; their teeth face each other, but only one engages with C at any time. When desired, however, one can be put out of, the other in, gear with C, to drive the latter in either direction.

A spur wheel D is keyed upon the tappet shaft B′, and gears with a pinion C′ ; it contains a bolt-hole for each pick in the round of the tappet ; these holes are concentric with B′, and equidistant from each other. Bolts are passed through the holes, and a plate F, similarly drilled, is dropped

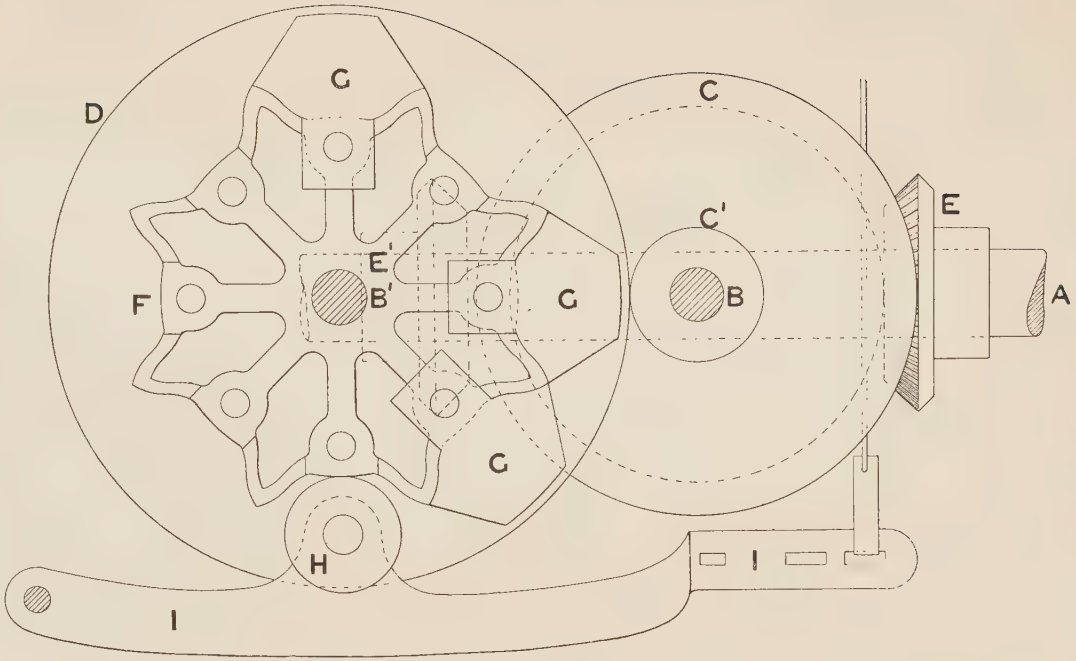


FIG. 26.

over them. The periphery of F has a slight curve over each bolt-hole, and tooth-shaped projections between them. Every bolt-hole in F passes through the centre of a slotted recess prepared for the ear of an interchangeable plate G, which fills the space between two teeth and projects above them. A plate G sinks a shaft, and a depression in F permits one to rise. When reading from a tie-up, sinkers are placed where required upon as many plates F as there are shafts to be used, and all are then bolted firmly together. The treadles I are mounted below the tappet plates, and as the antifriction bowls H bear upon F the shafts are pulled down, but springs attached to a frame above the loom lift them.

For open shedding four differently shaped sinkers are used—one to lower a shaft for a single pick, two others serve as right- and left-hand sinkers respectively when a shaft is to remain down for two or more picks, and a fourth holds a treadle bowl in one plane as it rolls against the tappet. In all segment tappets the plates are liable to work loose, and the bowls H then slip between two plates; with this exception they are valuable shedding motions.

The Barrel Tappet

Another negative tappet known as the barrel motion is fixed above the heald shafts with its axis at right angles to them. It is driven either from the bottom, or the crank shaft by an upright shaft A, and bevel wheels B, Fig. 27. The shaft A sometimes passes through the warp, direct to the large tappet bevel, but it is preferable to fix it to the end framing, and drive the tappet D by a short horizontal shaft C. This arrangement necessitates the use of two additional bevels and a shaft, yet the warp space of a loom is left unobstructed.

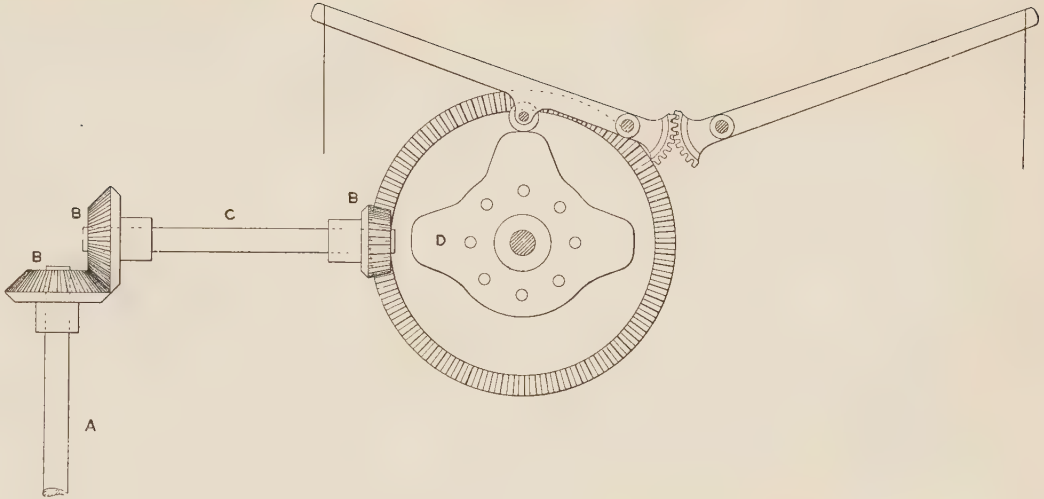


Fig. 27.

The tappet may consist of a series of solid plates bolted, or cast together, or of interchangeable sections bolted upon plates; if made in separate plates, a hole is left in each exactly in the centre of every pick, so that by turning similar plates into different positions with relation to each other, many patterns may be woven from them. If the

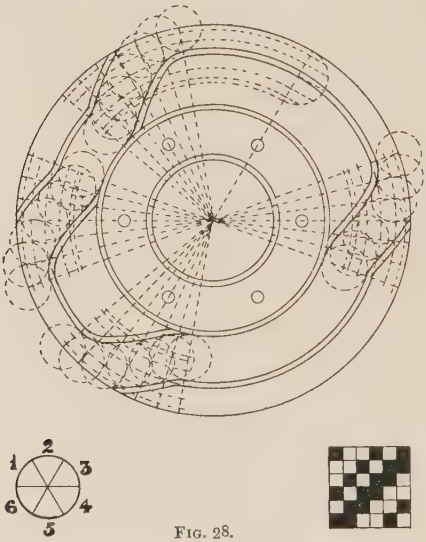


FIG. 28.

tappet is cast in one piece, fewer changes are possible; but, on the other hand, it is solid, and there is no risk of bolts working loose. Two treadles are connected to each other by toothed segments, one of which rests upon a tappet, and cords from the treadles provide connections for the heald shafts. The upward movement is positive, but springs or other appliances pull the shafts down.

When arranged for cross stripes or bordered fabrics requiring two patterns in the same piece, a barrel is

furnished with two plates for each shaft to be moved, and the treadles act on alternate plates at one time. By operating one lever all the treadles are taken out of contact with the tappet plates, and by operating another, the remaining series of plates are brought under the bowls to weave the second pattern, after which the bowls are again lowered into contact with the tappet.

Positive Tappets

A positive tappet, of the type shown in Fig. 28, consists of a metal disc, upon one face of which two flanges are cast for a treadle bowl to work between them. In constructing such a tappet the method employed is similar to that for a negative one, except in the lift, and there at least $\frac{1}{8}''$ must be added, because the space between the outer and inner flanges must exceed the diameter of the treadle bowl by that amount, to give freedom of movement.

In setting out such a tappet it is usual to add $\frac{1}{8}''$ to the lift, and after finding the points of intersection between the radial and concentric lines, as explained on p. 41, to describe circles round each, of a diameter exceeding that of the treadle bowl by $\frac{1}{8}''$. Lines are then traced, touching the periphery of each circle at two points; which lines are the inner and outer flanges. To these sufficient thickness must be added for strength and sufficient depth for the bowl to roll against. In Figs. 28, 29, and 32, the outer flange is broken, but there are tappets in which that flange is continuous except at one place, and there a portion is removed to allow an antifriction bowl to be dropped into, and lifted out of, position. If a treadle is above the tappet centre, as in Figs. 14 and 19, an inward curve on the outside flange causes a shaft to lift, and an outward curve on the

inner flange causes a shaft to sink. But if a treadle is beneath the tappet centre these conditions are reversed.

Woodcroft's Tappet

In 1838 Bennet Woodcroft patented a positive tappet

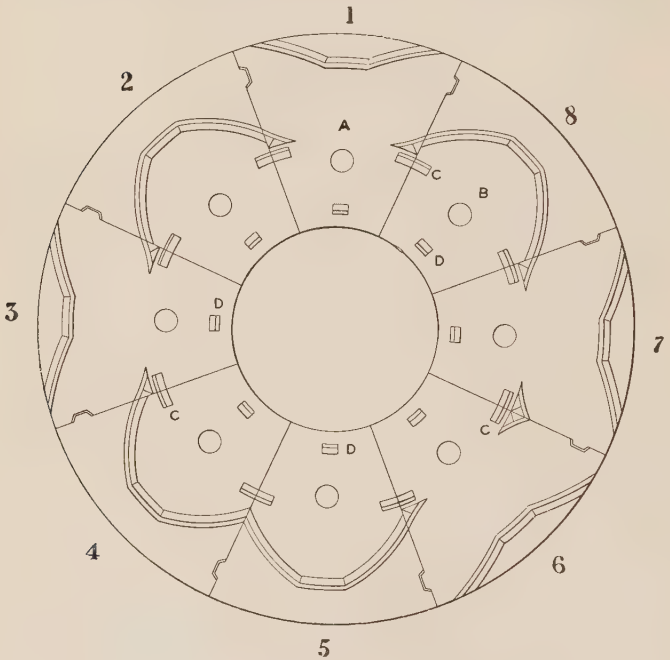


Fig. 29.

that is still used for heavy work, and for eight or more picks to the pattern. The makers advertise it for 56 picks to the round, but in practice the useful limit is reached at 20 or 24 picks.

It consists of corresponding sections cast with an

elevator or depressor on each, and, when placed together, they form one plate. By changing the relative positions and thus forming new combinations of sections, patterns may be varied at small cost, provided the picks in the new pattern equal the number of sections in a plate, or that two or more repeats are contained on a plate. For example, in a tappet for 16 picks, a section equals $\frac{1}{16}$ of a plate, therefore any pattern of 2, 4, 8, or 16 picks can be made by suitably arranging the same sections; but if a pattern has any other number of picks, new sections must be used. In Fig. 29 A shows the form of an elevator, and B a depressor.

FIG. 30.

Dark squares on the slip of design paper, Fig. 30, indicate a rising shaft, and blank squares a sinking shaft. As eight squares are shown, eight to the round sections are employed, and they must be placed to correspond with the position of the tappet in a loom and the direction of its motion. If fixed at the right-hand end of a loom, to revolve in an opposite direction to the crank shaft, pass a number of bolts through the holes provided in the tappet wheel, and place the latter horizontally on a stand. Lay an elevator in position for number 1 on the design paper, and follow with a depressor for number 2 on the left side of number 1. Continue reading from the design and laying the sections until all are in position; then lock the sections by placing the outer flange of a ring, Fig. 31, above the projections C, and the inner flange below those of D, Fig. 29. Proceed to form other circles of sections from similar slips of design paper, one for each heald shaft employed, always beginning immediately above number 1 of the first plate. When complete, bolt all together and the tappet is ready for use. If a tappet revolves in the same

direction as the crank shaft, lay the second section on the right of number one.

A tappet fixed at the left-hand end of a loom, to revolve in an opposite direction to the crank shaft, requires a ring to be first placed upon a blank plate on the tappet wheel, and the second section to be laid to the right of the first. All sections are laid face down, to permit the treadle bowls to run in the groove between

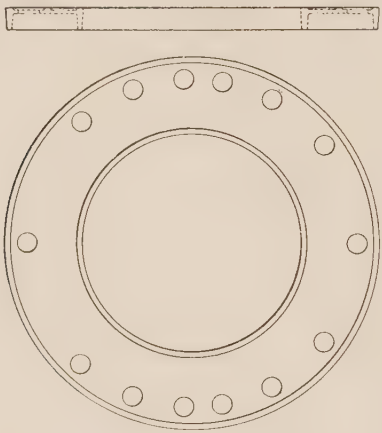


Fig. 31.

two plates. Because, with treadles on the right hand, the bowls face the loom, but if on the left hand they face away from the loom. By attaching the bowls to the opposite sides of the treadles, the sections could be laid face up. If the tappet is to turn in the same direction as the crank shaft, lay the second section on the left of number one.

Woodcroft's tappet is now made for open shedding, but the parts are somewhat complicated, for, in place of using

duplicates of two sections throughout, eight distinct sections are necessary -namely, ordinary risers and sinkers, right- and left-hand risers, right- and left-hand sinkers, riser

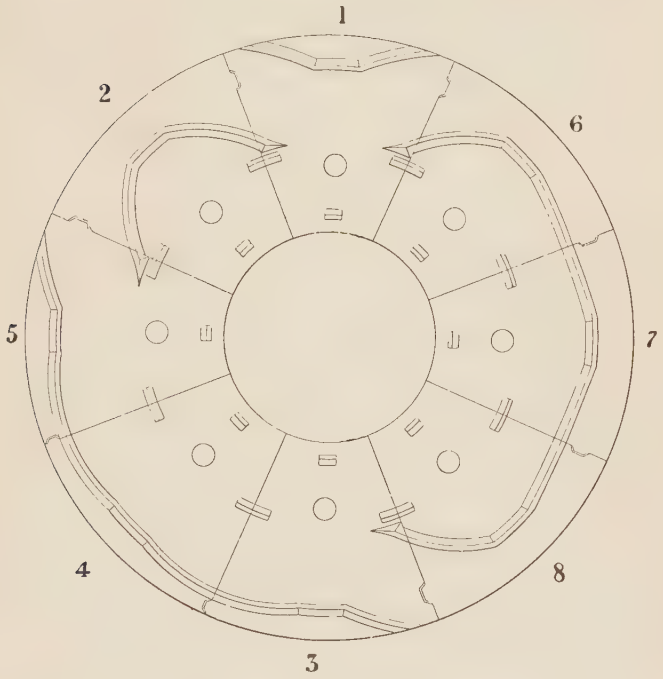


Fig. 32.

dwells and sinker dwells; the two last-named refer to sections that hold the treadles stationary.

Each section is clearly shown in Fig. 32: number 1 is a riser; 2, a sinker; 3, a left-hand riser; 4, a riser dwell; 5, a right-hand riser; 6, a left-hand sinker; 7, a sinker dwell; and 8, a right-hand sinker. With the above

exceptions, these sections are laid in the manner described on the preceding pages.

In Fig. 33 an antifriction roller F is carried by a treadle G, and G is centred at E. The treadle is pushed up and down by the rotating sections, and imparts an oscillating motion to the outer end of G. Straps and cords pass from

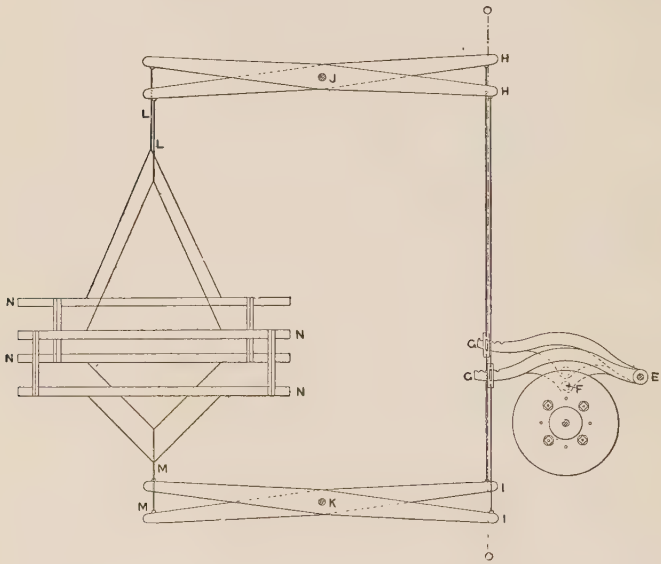


FIG. 33.

a treadle to the top and bottom jacks H, I, which are fixed in the loom at right angles to G; but in the sketch are turned 90 degrees from their true positions in order to show the parts more distinctly. The dotted line O indicates the hinge on which the parts are assumed to be turned. The fulcrum pins of H, I are shown at J, K; and cords, L, M are attached to the top and bottom heald shafts;

therefore if a treadle G is raised, a shaft N is depressed; also if G is depressed, N is raised.

A Woodcroft tappet is less firm than one made from solid plates, and where there is no outer flange the treadles tend to leave the tappet unless the warp threads put considerable strain upon the shafts. This may be minimised by attaching springs or weights near the fulcra of the treadles to hold them down, and thus keep the bowls in contact with the tappet.

The Oscillating Tappet

Since 1840 chains of various kinds have been used as shedding motions. The first was invented by George Clark, the second by John Knowles in 1859, and there are several others. One of the best of them was patented by William and Thomas Nuttall in 1872. Their chain is composed of rollers A and collars B, Fig. 34, which are threaded upon long spindles C, to form a separate row for each heald shaft employed, the spindles being connected at both ends by flat links D. A roller causes a shaft to lift, a collar causes one to sink, and the bowls and collars hold each other in place upon a spindle. The chain is divided in two parts—one providing for all the odd picks, and the other for all the even picks. Both are passed round octagonal barrels E, that turn in bearings attached to the tappet. Flat pieces of metal F are weighted at their outer ends, and form parts of elbow levers F, G; these rest upon the chains, and are lifted by a roller, but fall by gravity if a collar is beneath them. The arms F impart a corresponding motion to the arms G, and from each arm G a projecting stud H enters a slot in a tappet plate I, I. The plates I, I are fulcrumed at J, J, and lifted by a roller

into the position shown at I, on the right of the drawing, but a collar leaves them, as at I on the left. The tappet makes one complete oscillation for two revolutions of the crank shaft, in the following manner :—A pinion 1, Fig. 35, on the crank shaft drives a carrier wheel 2 round a stud M, and 2 gears with a slide wheel 3 ; the teeth in 3 are in the proportion of two to one in the pinion. A boss compounds

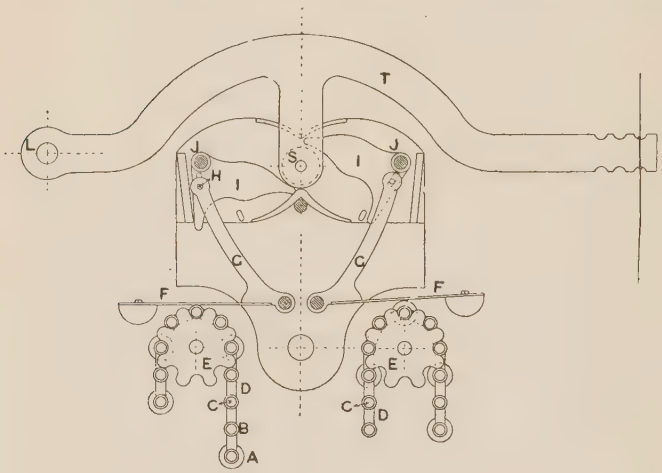


FIG. 34.

the wheel 3 with an eccentric 4, so that both revolve upon a stud K. By means of a strap, and an arm N, a connection is made with a lever O, which is centred at P. A second arm Q is fastened to O, and to the tappet by a pin R. As the eccentric 4 revolves the tappet rocks ; if to the left, the treadle bowl S, Fig. 34, will run along the under side of I, depress a treadle T, and cause a heald shaft to lift. But if the tappet rocks to the right, S will roll along the upper

side of I, lift T, and depress a shaft, for the heald connections are similar to those of a Woodcroft tappet, see

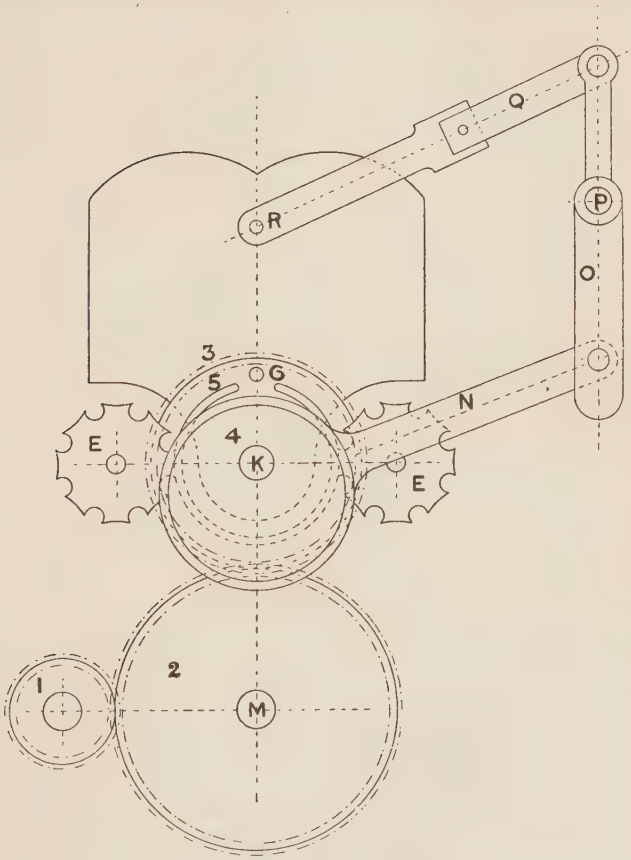


FIG. 35.

Figs. 14 and 33. A bowl S can run above or below the plates I, I any number of times in succession; its course

depends upon the construction of the chains, which are rotated, by slide and star wheels, to place the picks progressively in the fabric. Thus, the slide wheel 3, Fig. 35, has a circular flange 5, shown broken at the top where a stud 6 is inserted. The star wheels E, E are respectively keyed upon each chain barrel, and as the slide 3 revolves it carries the stud 6 alternately into a notch of the star wheels E, E; and a barrel is turned $\frac{1}{8}$ of a revolution.

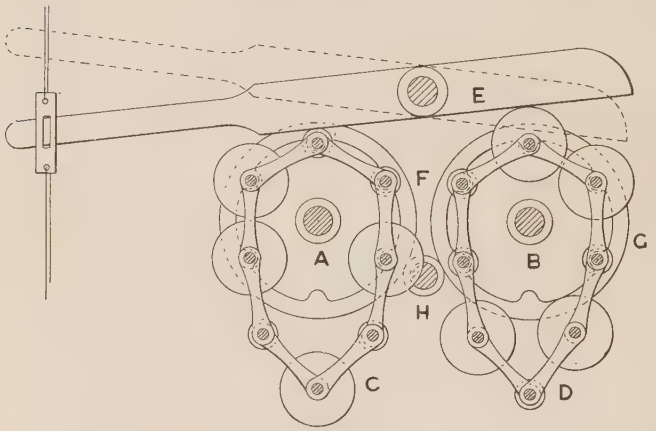


Fig. 36.

Hence one link of the pattern chain acts upon one set of levers F, G, Fig. 34, to prepare for the next shed, while corresponding parts on the other side are forming a shed for a shuttle to pass through. When the reed and cloth are in contact all the treadles T are level, the bowls S are over the centre of the tappet, and the tappet midway between the extremes of its oscillation. Immediately a shed is fully formed the peg 6, in the slide wheel 3, will have turned that barrel E which occupies the lowest position.

Flat steel cards have been added to this tappet in order to effect economies in the pattern chains, but they are better adapted to the production of diaper fabrics in which the weave is reversed at intervals than to the general run of goods.

This motion is positive, and if the tappet centre is placed above the crank shaft, patterns of from 80 to 100 picks can be woven, by reason of the chain being divided in two parts. The same bowls, collars, and spindles when rearranged can be used for all patterns, but the tappet is suitable for heavy rather than light fabrics.

A tappet introduced by Grube and Hall, in 1887, has a pendulum lever suspended from each treadle, and an anti-friction bowl is fitted at the base of each lever to run above or beneath curved plates, similar to those in the oscillating tappet. The chief difference between this tappet and Nuttall's consists in vibrating the pendulum levers every pick and leaving the tappet stationary, also in the use of lags instead of bowls and collars.

Nuttall's Chain

Another positive chain tappet, patented by William and Thomas Nuttall, in 1872, is also used where heavy goods are made. It is placed in a stand that can be fixed to the floor at the end of any loom, and driven by a pinion from the crank shaft. It consists of two parallel chain barrels, A, B, Fig. 36, which are mounted in suitable bearings, and rotate the chains, C, D, at the required speed by two spur wheels, F, G, keyed upon the barrel shafts. These wheels are in gear with a small carrier, H, that turns both in the same direction. The chains are composed of similar rollers and collars to those for an oscillating tappet,

but here a collar on one barrel must be opposite a roller on the other, as both chains move at the same time, and act upon the same straight levers E, one of which is shown resting upon them. Each lever is fulcrumed midway between the centres of A, B; with its rear end projecting slightly beyond B, and its forward end long enough to permit of connections, similar to those in Figs. 14 and 33, being made to the upper and lower jacks.

This tappet is not so suitable for long patterns as the oscillator, for a link of each chain is required for a single pick; the first to lift the rear ends of E and the shafts; the second to lift their forward ends and depress the shafts; but it is positive in action and simple in construction.

A Continental machine of more recent date only differs from the above in having antifriction bowls fitted to the under side of E, and a chain made of links, resembling those of Diggle's shuttle-box motion, see Figs. 209 and 210.

Scroll Tappets

Scroll tappets are chiefly used to weave narrow stripes and chain effects; they govern threads that rise for three, four, or more picks in succession, and then remain depressed for an equal number of picks, while the remaining warp is actuated by tappets of the usual form, and to which the scroll plates are bolted. As a shedding motion the scroll is not a recent invention; it is similar in construction to a picking scroll (see Part X. Fig. 196), but the half-moon is attached to a tappet treadle. A scroll plate makes two revolutions for one repeat of the pattern, hence, if used in conjunction with a four to the round tappet, the scroll will hold its heald up for four picks, during which time the

half-moon traverses the inner groove; it then changes to the outer groove and holds the heald down for four following picks.

Other tappets are to be met with, which do good work, but want of space precludes a detailed description.

Tappet Driving

Tappets are driven, directly or indirectly, from the

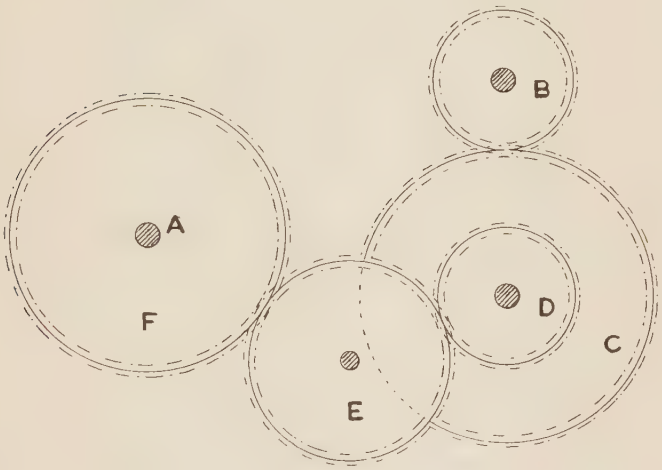


Fig. 37.

crank shaft by spur wheels. When convenient, a large wheel is fitted on the tappet and a small one on the crank shaft, and their relative dimensions determine the speed of the tappet; thus a 4-picked tappet requires a wheel with four times as many teeth as that on the crank shaft, also, if a 2-picked tappet has a wheel containing 120 teeth, the number of teeth in the driving wheel $= 120 \div 2 = 60$.

If with 5 picks to the round, $120 \div 5 = 24$ teeth. But it frequently happens that two wheels will not answer, because both shafts occupy fixed positions, and unless the wheels are the proper size they will not gear; in such cases carrier wheels are employed. A single carrier will cause a tappet to revolve in the opposite direction to

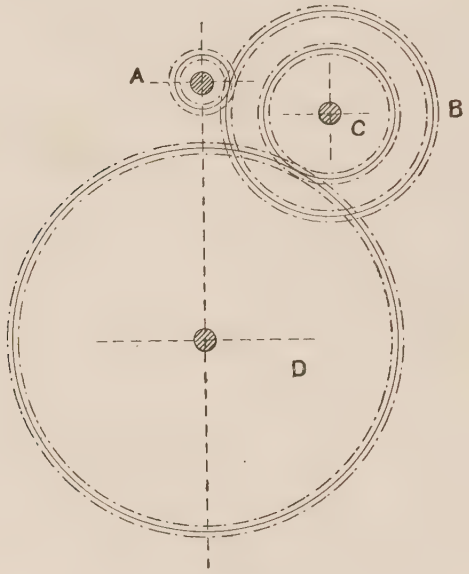


FIG. 38.

one directly driven, or to one with two carriers. Fig. 37 shows the driving for tappets which are placed under the healds, and fixed upon a short shaft A. Motion is given to A by the crank wheel B, the bottom shaft wheel C, a wheel D, which is compounded with C, a carrier E, and a tappet wheel F. If B = 40, C = 80, D = 20, and F = 40

teeth respectively, the revolutions of A will be to those of the crank shaft as 1 : 4, for,

$$\frac{40 \times 20}{80 \times 40} = \frac{1}{4} = 1 : 4.$$

The carrier wheel E is omitted from the calculation as it merely conveys motion from D to F, without influencing the values of B, C, D, F. Plain cloth tappets with 2 picks to the round are generally keyed to the bottom shaft, because the revolutions of that shaft $= \frac{1}{2}$ those of the crank shaft, and other gearing is unnecessary.

Compounded intermediate wheels are used to drive tappets having a large number of picks to the round; the intermediate wheels then work loosely on a stud, the larger one gears into the crank shaft wheel, and the smaller one into the tappet wheel,—as in Fig. 38, where A is the crank shaft wheel, B the large, and C the small stud wheels, and D the tappet wheel. A, C are thus driving, and B, D are driven wheels. A tappet wheel can rarely be changed, but the sizes of the three remaining wheels can be found by dividing the tappet wheel by any number that will not leave a fraction. The divisor will give the teeth for one pinion, the quotient will give those for the other; the picks to the round give the first driven wheel; the tappet wheel being the second. Thus, in a 16-picked tappet, having a wheel of 180 teeth—

$180 \div 15 = 12$ ∴ 12 drives 16 (the picks) and 15 drives 180.
For proof:—
$\frac{15 \times 12}{16 \times 180} = \frac{1}{16}$ or 1 revolution of the tappet to 16 of the crank shaft.

If it is assumed that a wheel with fewer than 20 teeth cannot be used, any multiple of the numbers obtained will answer, as 15×2, 12×2; but since the tappet wheel is

fixed, 16 must be multiplied by 4, because the teeth in the driving wheels have been increased fourfold, and the same ratio in the teeth of the driven wheels must be maintained.

$$\therefore 16 \times 4 = 64. \quad \text{For proof } \frac{30 \times 24}{64 \times 180} = \frac{1}{16}.$$

By the following rule both intermediate wheels can be found if the crank pinion and the tappet wheels are given.

$$\text{Thus: } \frac{\text{Picks required} \times \text{pinion}}{\text{Teeth in tappet wheel}} = \frac{B}{C}. \quad \text{Fig. 38.}$$

Example.—If a pinion of 20 teeth and a tappet wheel of 120 teeth are used to drive a tappet having 12 picks to the round, what intermediate wheels are required?

$\frac{20 \times 12}{120} = \frac{2}{1}$ $\therefore$ any wheels in the ratio of 2 to 1 are available.

A change made in one wheel of the train is often sufficient; it may be either a driver or a driven, but the rules are—

$$\frac{\text{Driving wheels} \times \text{picks to the round}}{\text{Driven wheel}} = \left\{ \begin{array}{l} \text{teeth required for a} \\ \text{driven wheel;} \end{array} \right.$$

and

$$\frac{\text{Driven wheels}}{\text{Driver} \times \text{picks to the round}} = \text{teeth required for a driving wheel.}$$

PART IV

OVER AND UNDER MOTIONS

All negative shedding requires the addition of parts known as over or under motions to reverse the direction

of movement in healds. The terms over and under refer to the positions of these devices when in use. If a tappet is placed under the healds, an over motion is used, but if placed over the healds, or at one end of a loom, an under motion becomes necessary. Reversing motions may, however, be grouped as A, single-acting; B, compounded. In the former, each part is only capable of controlling one shaft; but in the latter, each part can be made to act simultaneously on all the shafts in a set except one. Before proceeding to describe these motions, it will be necessary to consider the nature of the work to be done by them.

Since a negative tappet moves a shaft in one direction, a reversing motion should act immediately a tappet ceases, and continue in action to the termination of the shaft's journey, where its maximum force should be exerted until the tappet is again brought into use. During the active period of a tappet little force is needed to keep a moving shaft steady, more than this is wasted energy. These remarks apply specially to centre and open shedding, for in both the tense warp exerts its greatest force to pull the shafts to the closed shed line when the reversing gear is alone available to resist such strain.

Single-acting Reversing Motions

Single-acting reversing motions generally consist in attaching to the heald shafts dead weights, spiral springs, or elastic cords, but none of them are mechanically correct. A weight exerts a constant force, whether the tappet is acting or has ceased to act. This is undesirable, and although weights are invariably employed for Jacquard shedding, they have not met with much favour when

applied to shaft work; for one reason, if weights are free at one end, a rapid vertical reciprocating motion sets up a lateral swinging action, and considerable friction results. Another objection to their use is that the shorter the time during which weights fall, the slower they move; this may result in changes being completed in one part of a harness before they are completed in another part.

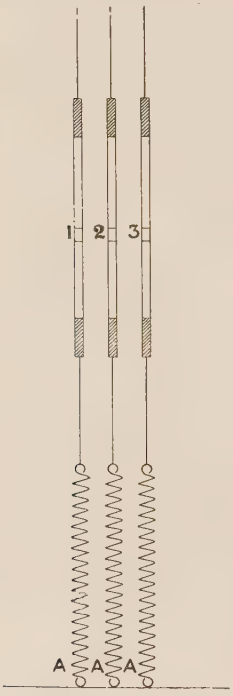


FIG. 39.

As usually applied, a spiral spring is stretched until it exerts sufficient force to hold a heald shaft on the top or bottom line when the tappet is inoperative; hence the farther a heald moves from that position, the more a spring is stretched, and the greater the force it exerts to oppose that of the tappet. On the latter ceasing to act, a spring exerts its maximum force to pull the heald shaft in the opposite direction, but as the spring contracts, its force decreases in proportion to that of its increase when stretched; so that where its effectiveness is most needed, it exerts a minimum force. A spring is, therefore, one of the most defective pieces of mechanism that could be devised to reverse movement in healds; it is strongest where it should be weakest, and weakest where strength is most required.

A comparison of the power consumed by springs and dead weights will make this point clear. Let it be assumed

that a force equal to a weight of 10 lbs. is needed to hold a heald shaft stationary, then a spiral spring must be stretched until it is capable of resisting that force. Let it be further assumed that such stretch = 1″, and the movement of the heald = 4″. Since the force of a spring increases uniformly $10 \times 4 + 10 = 50$ lbs., the force exerted when it is not wanted, and 10 lbs. its effective force. Or put into units of inch pounds, $10 + 50 \div 2 = 30$ lbs., the mean force, and $30 \times 4 = 120$ inch pounds.

A dead weight of 10 lbs. exerts a constant force in all positions, ∴ inch pounds $= 10 \times 4 = 40$. Hence, under the above conditions, the work done during one movement of a shaft is, with weights, 40 inch pounds, and with springs 120 inch pounds.

Fig. 39 shows the usual application of springs; A, A, A are three springs attached by their basal ends to a bracket placed near the floor line; from the upper end of each spring a cord passes to the lower heald shafts 1, 2, or 3. It is customary to use two springs for each shaft and to connect them at equal distances from either end. Springs operated in this manner are first stretched sufficiently to hold a heald in position, and then to correspond with the lift of a heald.

Notwithstanding the faults inherent in spiral springs, they are more extensively used, for light and medium fabrics which require six or more shafts, than any other appliance, probably because they are readily fixed, easily understood, and can be employed to weave any pattern. Inventors have so applied springs that their stretch shall be less than the movement of the healds. Figs. 40, 41, and 42 illustrate three plans by which this may be attained. In Fig. 40 a heald is connected to segment levers, A, A, at C, C, and, at $\frac{1}{5}$ the distance from the fulcra, springs D, D are

attached to the same levers. The stretch of D, D will therefore equal $\frac{1}{5}$ the movement of a heald shaft, but a

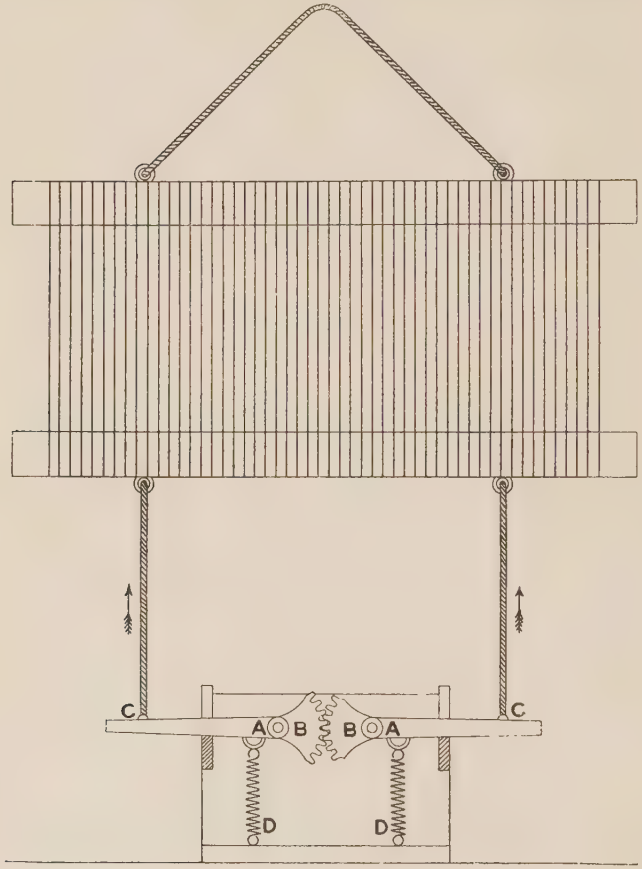


FIG. 40.

spring of a given strength will be $\frac{4}{5}$ less efficient at D than at C. Hence a spring five times as strong must be employed,

and the force required to stretch it will approximate to that needed for a spring as ordinarily used. Other inventors have so arranged springs that as a shaft moves their full force will not be exerted upon it, as in Figs 41 and 42.

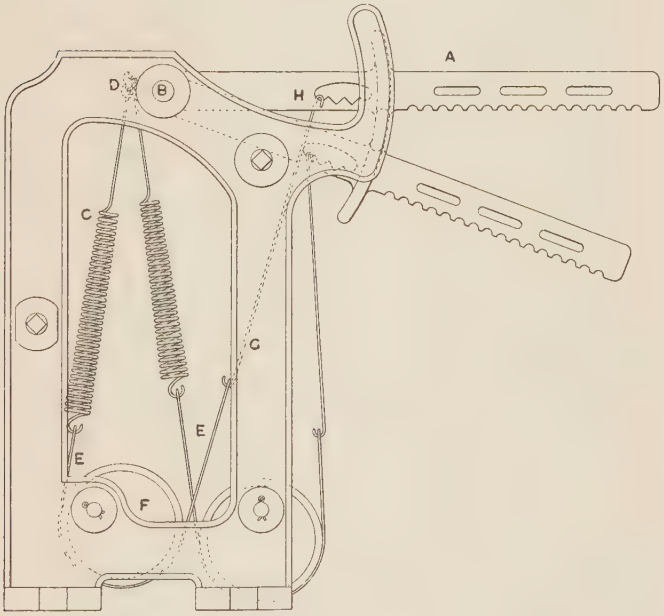


FIG. 41.

SPRING-EASING REVERSING MOTIONS

Messrs. Hahlo, Liebreich, and Hanson's patent reversing motion is simple in construction, and not liable to get out of order. It consists of levers A, Fig. 41, which are fulcrumed at B, and to the rear end of each a spiral spring C is either connected by a wing-nut and screw, for the

purpose of regulating the tension, or it is hooked upon A, as shown at D. The lower end of C is fastened to a strap E, which is set-screwed upon an eccentric F, and E is united by a hook G, with the lever A, at H.

Since a heald shaft is connected to the outer end of A, and A and G ascend together, G will draw a part of the strap E from the large side of the eccentric F and wind another part of it upon the small side; but A moves down at D simultaneously, and prevents the spring C from stretching in proportion to the length of strap wound upon the eccentric F. The surface of F and the positions of D and H are such that, for a movement of 5″ in a shaft, the spring C will be stretched $\frac{3}{4}$″; this results in a considerable reduction of power as compared with springs used in the ordinary way. Thus, on the former assumption of 10 lbs. equalling the weight required, and also a stretch of 1″, an ordinary spring will exert a force upon a lifted heald of $5 \times 10 + 10 = 60$ lbs., but used as above it equals a force of $10 \times \frac{3}{4} + 10 = 17\frac{1}{2}$ lbs.

Kenyon's Reversing Motion

Kenyon's motion is equally simple, but it acts in a different manner upon the shafts. In Fig. 42 two chairs, A, B, are placed back to back and bolted upon a rail C to support the moving parts. In case the spring D is too strong or too weak, the chairs may be moved nearer to or farther from each other. Two chains E, F are hooked into opposite ends of D, and are respectively connected to the curved levers G, H; the latter are fulcrumed at I, J, and carry at N, O eyed links, from which straps K, L pass to a shaft M.

The levers G, H cause the spring D to rise and fall

with the shaft, and as D rises its rate of stretch decreases. Further, its leverage decreases as it approaches the line of the fulcra I, J, with the result that the actual stretch of a spring does not represent the force applied to a heald.

For example, a trial showed that a lift of 5″ stretched a spring $2\frac{3}{4}$″, and this, under the previously assumed conditions, would equal $2\frac{3}{4} \times 10 + 10$, or $37\frac{1}{2}$ lbs. when at the highest point, and 10 lbs. when at the lowest. But a spring balance gave the following stresses for each inch of movement:—Closed shed, $12\frac{1}{2}$ lbs; first inch of lift, $11\frac{1}{4}$

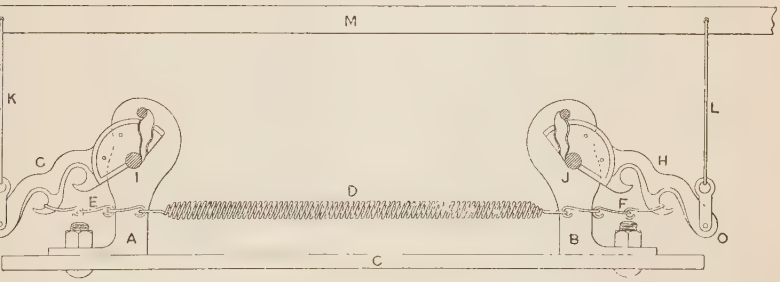


FIG. 42.

lbs.; second inch, $8\frac{3}{4}$ lbs.; third inch, $6\frac{3}{4}$ lbs.; fourth inch, $5\frac{1}{2}$ lbs.; and fifth inch, $6\frac{1}{4}$ lbs. These figures show that springs may be more economically employed to reverse the actions of tappets than is generally the case.

COMPOUNDED MOTIONS

The second class of reversing motions, known as stocks and bowls, are all based on the compensating principle; which consists in making a rising or falling shaft help to move another in the opposite direction. When one of these devices can be successfully applied, the consumption of

power will be smaller than with weights, or spiral springs as usually employed.

Stocks and bowls consist of levers either circular or

FIG. 43.

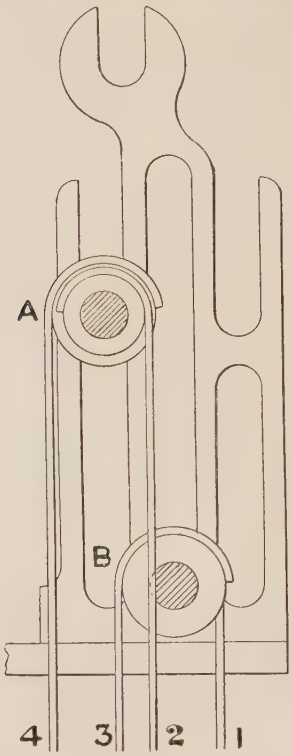


FIG. 44.

oblong in form, to which the shafts are connected, but they can only be employed when the same number of shafts are to be lifted for every pick. In cases where, say, two shafts are lifted for one pick, and three for another, a single motion must be used.

Shafts are sometimes connected in pairs to single levers, as seen in the over motions, Figs. 13, 17, 43, and 44; the three former arrangements being for plain, and the latter

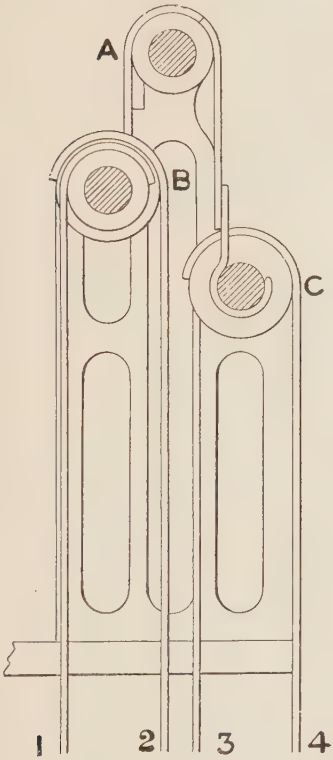


Fig. 45.

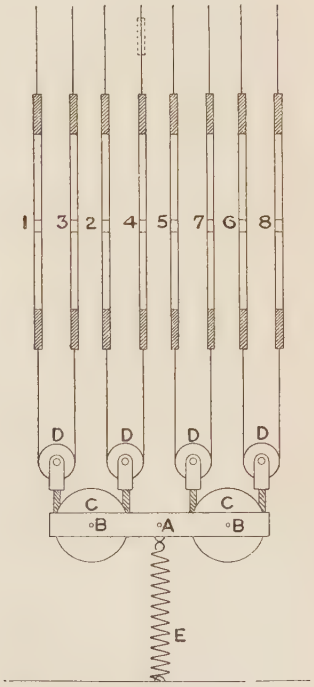


Fig. 46.

for twill weaving. This principle can be extended to work any even number of shafts, but half the number employed must be up and the other half down at each pick. In this form stocks and bowls are unsuitable for a large number of

patterns. When levers are compounded, as in Figs. 45 to 55, any constant number of shafts can be carried up or down for each pick.

Fig. 45 is an over motion showing an arrangement of bowls for moving four shafts. Two straps are set-screwed upon bowls A, to support bowls B, C, by means of hooks and rollers. Four straps, 1, 2, are secured upon separate bowls B, and attached to the heald shafts 1, 2; the straps 3, 4 are made fast upon four bowls C, and the heald shafts 3, 4. In over motions two separate bowls are used for each heald shaft connection, and those governing the most forward shaft are the smallest (see p. 44).

The under motion, Fig. 46, consists of a larger number of compounded bowls which operate eight shafts in a similar manner to the above. As the lever A, B, Fig. 46, and the roller A, Fig. 45, are essentially the same, a further description will be unnecessary.

For an odd number of shafts more bowls are placed at one end of the first lever than at the other; and the fulcrum of the first lever must ensure equilibrium; it is placed inversely to the number of shafts attached to each end. Thus in the 3-shaft under motion, Fig. 47, the bottom lever is divided into three equal parts, and the fulcrum placed at the first division from the heavy end. A is a spiral spring that serves as a fulcrum for the lever B; and C is a pulley secured upon B, but free to rotate. D, E, F are three heald shafts. Of these, D is connected to the lever B, at a point two divisions from the fulcrum, while the centre of C is only one division from the fulcrum. A band passes beneath the roller C to couple the shafts E, F.

When an under motion consists entirely of bowls, the two lower ones are compounded and a strap is screwed upon the periphery of each. The diameter of one bowl

must be to that of the other in inverse proportion to the number of shafts each controls. Thus in Fig. 48, which is for 3 shafts, the diameter of A is twice that of B, because a strap F, screwed to bowl A, is attached to shaft 3 only; while the bowl B has a strap D screwed to it and to the block of C; another strap, E, E, unites the shafts 1, 2.

Fig. 49 is a 3-shaft over motion, but is otherwise essentially the same as Fig. 48.

There are many modifications in the details of stocks and bowls, but by suitably combining a 2, 4, 6, or an 8 shaft motion with one for 3 shafts, any odd number up to 11 shafts can be worked. The following combinations for 5 and 7 shafts will sufficiently explain the methods:—In Fig. 50 a 3-shaft under motion, similar to Fig 48, is attached to one end of a straight lever A, and a 2-shaft motion, similar to Fig. 43, is attached to the opposite end. A is divided into five equal parts, and equilibrium is established by placing the fulcrum pin two divisions from the 3-shaft motion, and three divisions from the 2-shaft motion. Fig. 51 is similar to Fig. 50, but is composed entirely of rollers and intended to be placed over the healds.

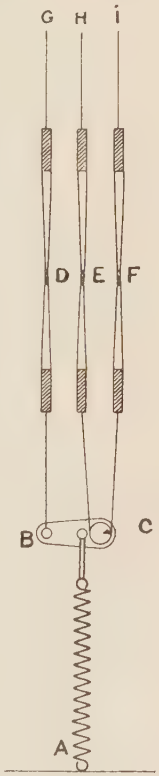


FIG. 47.

The Lacey over motion is of novel design and was patented by a Canadian inventor. It consists of an arm A, Fig. 52, which is bolted upon one end of the loom framing. A stud B is fixed in A, to support a loosely mounted lever C, whose arms are in the proportions of two to one. In the long arm of C a stud D carries

a stepped roller E, upon which two straps F, F are screwed, so that wire, strapping, and wooden guide rollers may provide connections for two heald shafts. The lower

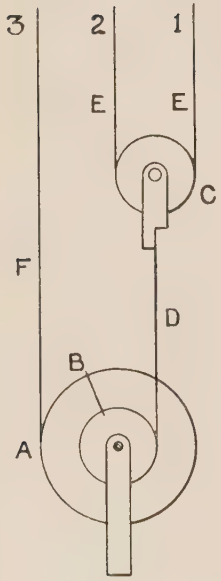


Fig. 48.

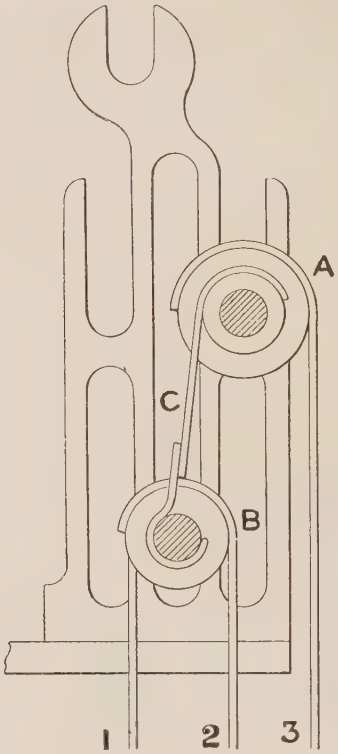


Fig. 49.

arm of C also carries a stud G, and upon it is a freely mounted lever H, whose arms are in the proportions of two to one. The long arm of H terminates in a curved face for a strap I to be screwed upon, and wire and

strapping unite I with a heald shaft. In the lower arm of H a stud J supports a second stepped roller K, and from K belts and wire make the connections with two remaining shafts. At the rear of levers C, H portions of each boss are

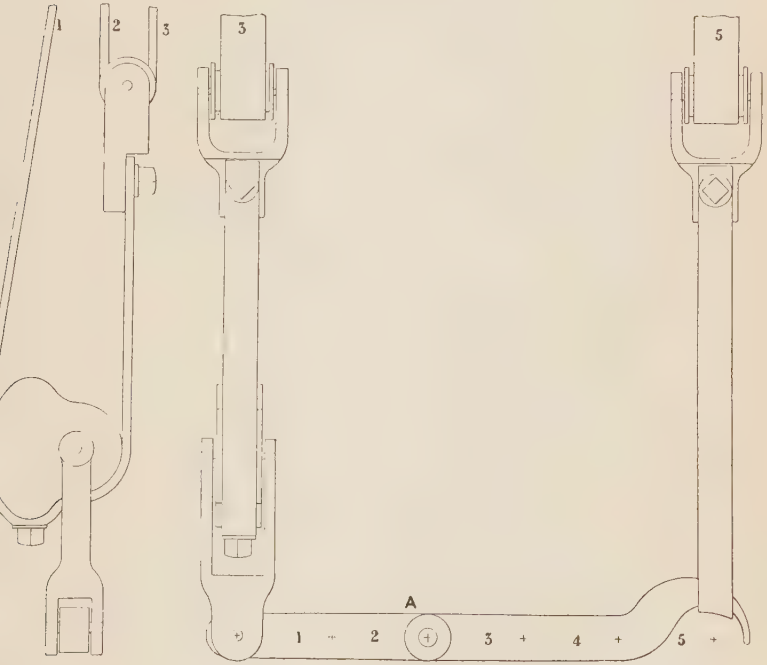


FIG. 50.

cut away to fit, when necessary, between flanges on the arm A and the lower part of C. When A, C are thus united C is prevented from rocking; and when C, H are united H is prevented from rocking independently of C.

If both levers C, H are locked in this manner, either E or

K may be used to actuate two shafts. Or both E and K may be used to actuate four shafts for a two-up and two-down pattern. By locking H only, any regular 4-shaft pattern

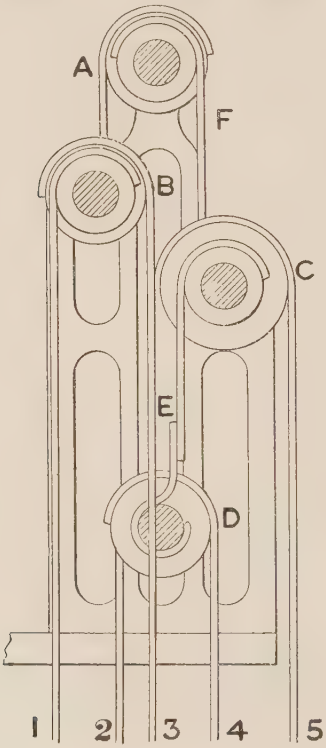


FIG. 51.

may be woven, for C will swing upon the stud B, and the rollers E, K are equi-distant from B. If only C is locked, the lever H and the roller K will serve as a 3-shaft reversing motion. With both levers C and H free, any 5-shaft pattern may be woven. Hence the device can be instantly

adapted to reverse the movements in 2, 3, 4, or 5 shafts.

Fig. 53 is also an under motion for actuating 5 shafts, but the diameters of the compounded rollers A, B are in the ratio of 4 to 1. A strap is screwed upon the surface of the small roller B, and is connected to a roller C. Round C a second strap is passed to govern the rollers D, E. A third strap from the roller D is connected to shafts 2, 3,

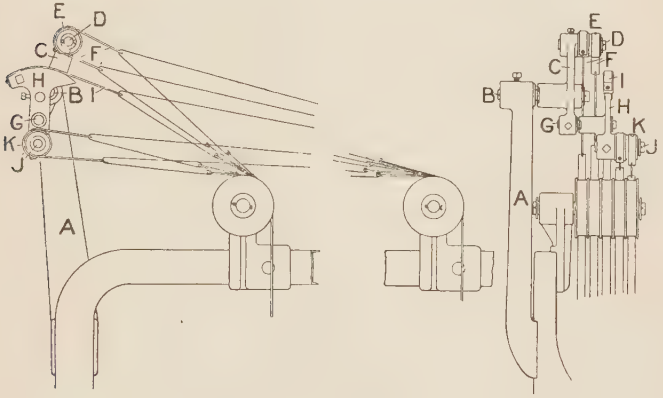


Fig. 52.

and a fourth from E is connected to shafts 4, 5. A fifth strap is secured upon the periphery of the large roller A, and connected directly to No. 1 shaft.

In Fig. 54 the 3-shaft motion shown in Fig. 48 is retained, and a 4-shaft motion, similar to Fig. 45, is added to the opposite end. The lever B is now divided into seven parts, and the pin placed at the third line from the heavy end.

Springs either flat or spiral are used, as in Figs. 46, 47, and 54, to neutralise imperfections in tappets and rollers

by permitting the entire set of stocks and bowls to make a slight vertical movement whenever excessive strain is put upon any of the straps. Also in Figs. 43, 46, 47, 48, 50,

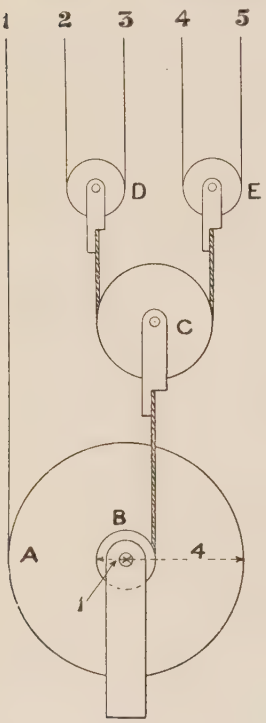


Fig. 53.

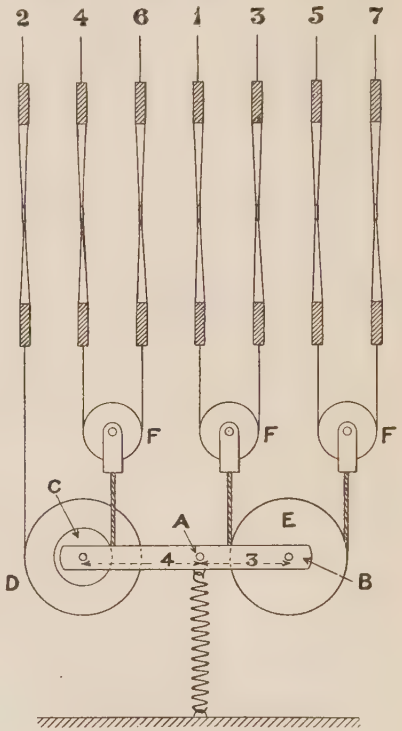


Fig. 54.

53, 54, and 55, plain rollers are used, but they should be replaced by stepped ones, and the stepping should be in proportion to the lift of each heald, as described on p. 44. Even then, as looms are now made, correctly shaped tappets and correctly stepped rollers may be nullified by attaching

the heald connections to the treadles in the wrong places.

In order to prevent stocks and bowls from giving a side pull to the healds it is usual to employ two sets, each set placed at the same distance from the extremities of the

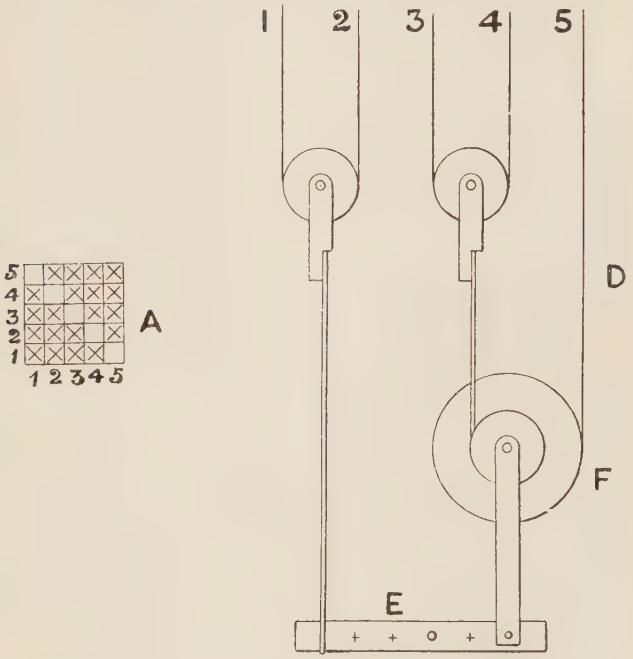


FIG. 55.

shafts; and to avoid twisting the straps, between the rollers and shafts, the axes of certain upper rollers are frequently at right angles to those below. In Fig. 50 such a set is shown in working position with the requisite connections to the shafts. The upper rollers place each strap immediately under the shaft to which it is attached.

Owing to the multiplicity of levers in large sets of stocks and bowls it is not always an easy matter to trace the movement of each roller when a shed is forming.

Something depends upon the character of the shedding motion. If, for instance, a Jamieson tappet, a single-lift, or a centre shed dobby is used, all the warp is placed in a line after each passage of a shuttle, but an open shedding motion acts differently, for all the shafts can never be at one height at the same instant. In tying them up, some are corded level with the top, others with the bottom sheds, and in these positions they remain stationary until the pattern renders a change necessary. The same number of shafts rise and fall every time a shed is formed, and those remaining stationary are fixed either at the top or bottom by the shedding motion.

In Fig. 55, assuming a 3″ shed is required, shafts 1, 2, 3, 4 must be up, and 5 down for the first pick; for the second, 5 goes up and 4 down 3″. The under motion at D shows that 3″ of strap will be unwound from the large pulley F, and $1\frac{1}{2}$″ wound upon the small one compounded with it. Shaft 3 being fixed, and the centre roller pulled down $1\frac{1}{2}$″, it follows that shaft 4 will be depressed 3″—namely, $1\frac{1}{2}$″ by the fall of the roller and $1\frac{1}{2}$″ by increasing the length of strap 3. A similar movement can be traced amongst the rollers and straps when any pair of shafts change places.

PART V

DOBBY SHEDDING

When a pattern is beyond the range of a tappet either in the number of shafts to be manipulated or in the picks

to a repeat of the pattern, and is at the same time too small to be economically produced by a Jacquard, a machine is employed which is known as a Dobby, a Witch, a Wizard, or an Index in different manufacturing centres. The number of shafts it may be called upon to actuate varies between 6 and 40.

In the cotton industry 24-shaft dobbies are in use; but the majority of them have from 12 to 16 shafts. Where dhooties are made 40-jack dobbies are common, but they work a mail mounting, and for such a purpose may be considered as small Jacquards. In the worsted industry dobbies with 36 jacks and upwards are in use; many of them are positive in action, and on that account are specially suited for heavy shedding.

In places where patterns are often changed, a dobby is used for fabrics well within the range of a tappet, as the former offers greater facilities for producing a variety of effects than the latter. Still, healds never work better, or last longer, than when actuated by properly constructed tappets.

The dobby probably preceded the Jacquard in the order of time; certainly it cannot be said to owe its existence to the larger machine, for machines were applied to the hand-loom, to weave patterns beyond the range of treadles before Jacquard's invention reached this country.

As now made, dobbies are single-acting, double-acting, negative, and positive; they form closed, centre, semi-open, and open sheds. See pp. 19 to 23. Their variety proves that no single machine is suitable for all classes of work. In practice one is slow in action, another is only adapted for light fabrics; some are complicated in construction, and in others wear and tear is excessive.

A single-lift negative dobby, Fig. 56, is placed over the

centre of the shafts, and contains a number of vertical hooks B, each having a bend at both extremities—that at the head to form a hook, that at the foot to permit a connection to be made with a heald shaft. The hooks

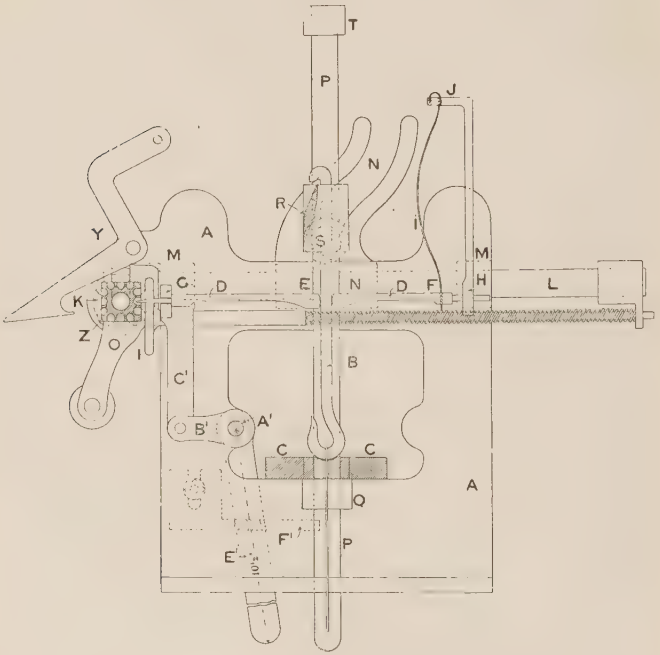


FIG. 56.

rest upon a perforated bottom board C, and each is kept vertical by a needle D, which is furnished with two eyes E, F; the eye E is formed by slotting and F by drilling the needle. A hook enters the slot, but a steel wire spring I is passed through the eye F, and its upper end is secured to a flat bar J. Two plates G, H are perforated to receive

the forward and rear ends of D and hold them horizontal. It is the office of the spring I to thrust the end of D through the needle plate G.

A square prism K, known as a cylinder, has holes drilled in each face to coincide with the pitch of the needles, and near the ends of each face two conical pegs are fitted to hold a chain of cards in position. This cylinder is supported by its gudgeons in open steps formed in brackets O, and the brackets are secured upon two bars L that slide freely in bearings, M, upon the end framing.

A cylinder requires a to-and-fro and a rotary motion. The to-and-fro motion is derived from two vertical rods P that hold a griffe bar R, either at right angles to the hooks B, or at a slight inclination to them. On the rods P are two bowls S, which work between the prongs of two forks N, and N are fast to the bars L. The rods P terminate in a cross-head T, and a link and pins attach T to a lever fulcrumed above the dobby framing. From this lever a connecting rod descends to a crank on the main driving shaft of the loom; hence, as the crank rotates, the rods P receive a vertical movement, and, by reason of the bowls S rising and falling in the curved slots N, a lateral reciprocating motion is imported to the forked brackets N, and also to the cylinder K.

Rotary motion is given to K by allowing a catch Y to rest upon the top face of a lantern Z. The lantern is secured to one end of K and consists of four rounded metal projections which are in line with the four corners of the cylinder. When K moves out, the catch Y engages a projection on Z and pulls it through an angle of 90°. K is prevented from turning too far, and assisted to turn its proper distance, by two T-shaped hammers 1, each having a shank long enough to pass through the dobby. Both

shanks are partly round, partly square in section; each has an open-coiled spiral spring loosely threaded upon the cylindrical portion to impinge against a bracket on the slide bars L, and also against the square part of its shank; hence the springs continually press the heads of I upon the inner face of the cylinder K.

A chain of perforated paper cards is passed round the cylinder and held in position by the conical pegs passing through special holes in the cards. The cards are punched to correspond with the pattern to be woven; each hole equals a rising shaft, and each blank a stationary shaft. The rotary motion of K brings the cards forward successively, and the horizontal motion allows the cylinder to turn, and to press a card against the needle points.

The action is as follows:—When the driving crank is on its top centre, the griffe R is about $\frac{1}{4}''$ below the heads of the hooks B, and the top edge of R touches those that are vertical; the bowls S are at the bottom of the forks N; the cylinder K is pressing a card against the plate G, and blank places in the cards push back the points of the needles D, for the springs I yield. The receding needles press their hooks out of the perpendicular, but a perforation in the card allows a needle point to enter without producing any effect on either needle or hook.

The rotation of the crank causes the griffe R to ascend with all vertical hooks, but all inclined hooks are left. While the griffe is ascending, the cylinder K moves out to permit the catch Y to turn K without injuring the needles, and place a fresh card in position for presentation. Each rising hook lifts a heald shaft until its warp is on the top line. But all unlifted hooks permit their healds to hold the warp they control on the bottom line; the process is repeated indefinitely.

This dobby is essentially a small Jacquard, with one row of hooks and needles. It forms a rising and falling shed with a stationary bottom line (see Fig. 9), and is only adapted for slow-running looms. It also has two other defects, namely, first, a griffe with a uniform rise and fall cannot readily place all the lifted warp threads level; and since the rear shafts must be lifted high enough to allow a shuttle to pass below the warp, the forward shafts rise too high, and unnecessary strain results. As shown on p. 31, each shaft should have a different lift, the front one the least, and the back one the greatest.

A simple alteration in the griffe, shown in Fig. 57, has rendered the machine perfect in this respect: A is the griffe bar which swings freely upon a fulcrum pin B carried by a bracket on the dobby front. A horizontal shaft C has two arms D, E fitted upon it, the former connected to A by a link F, and the latter to the driving crank by a rod G. As A vibrates the hook nearest the fulcrum pin will move through less space than that nearest to the link F; also the lift of each from front to back will gradually increase.

The second defect relates to the in-and-out traverse of the cylinder, which must cause the needles and hooks to be held back until the griffe is above the hooks to be left down. This is done by making the space between the prongs of N, Fig. 56, almost vertical for a short distance from the bottom, then as the griffe R reaches the same point in its descent, the cylinder K again presses back some of the needles, and if any of them actuate hooks already on the griffe, those hooks will be pushed off and gravitate to the bottom board. The tendency of this is to puncture the cards, bend both needles and hooks, and increase the wear and tear.

Of the attempts to remedy the last-named defect, the most effective is to drive the cylinder by a tappet, and

independently of the griffe. For a tappet can be shaped to give any desired movement; but the initial cost and the

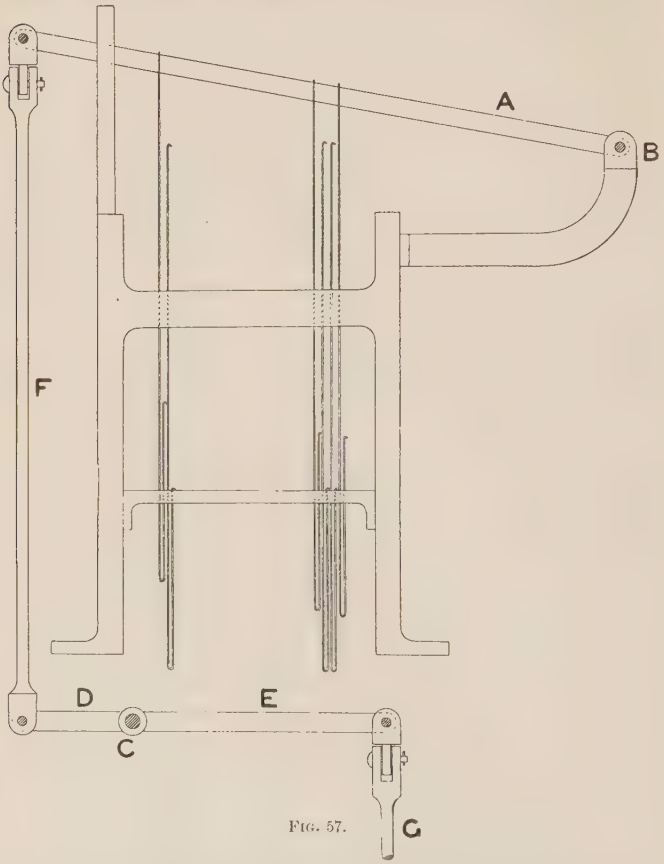


FIG. 57.

increased number of parts have prevented this plan from being generally used.

In 1884 J. E. Wadsworth attempted to attain the same

result by other means. He turned the hooks A, Fig. 58, round, and when vertical placed them out of reach of the griffe B; they were pushed upon B by blanks in the cards acting on short needles C, each needle being furnished with a disc instead of an eye. With lags in place of cards the pegs acted directly against the hooks.

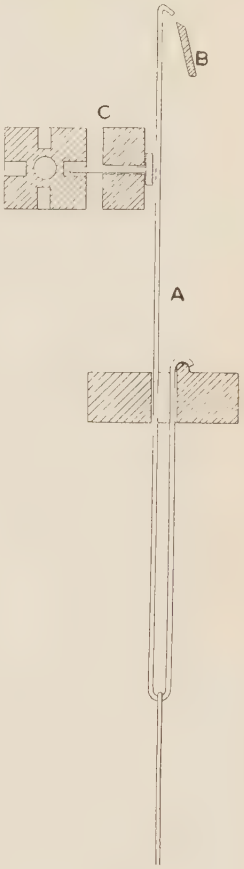


FIG. 58

Another contrivance is shown at Fig. 59, in which a needle A has three eyes; the first is large enough to receive a spring B, the second eye considerably exceeds the diameter of a hook C and takes its long leg, while the third is only large enough to take its short leg. Assuming a hook C to be on the griffe and a change to be necessary, a card will press back the point of a needle A some distance, without pushing C off the griffe, but the space between the long and short legs of C is decreased, and the natural spring of the wire carries the long leg off the griffe immediately the latter reaches its lowest point. In France a similar arrangement has for many years been attached to Jacquard machines, except that a needle has one eye which is large enough to embrace both branches of a hook.

Cards containing two or three rows of holes are often

met with on dobbies which have only one row of needles; they enable a manufacturer to produce striped or bordered fabrics from a few cards, as each row of holes is cut to weave a different pattern. The cylinder is drilled to

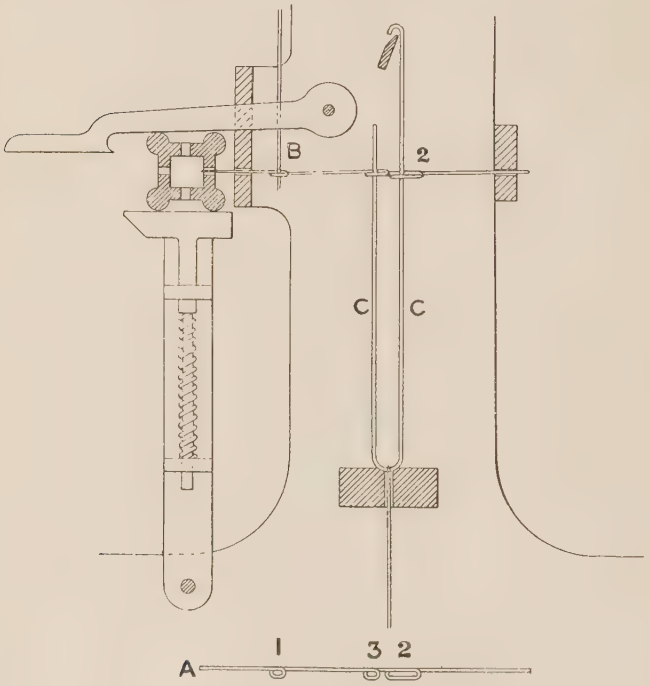


Fig. 59.

correspond with the number of rows in the card, and the dobby is said to be double-decked for two, and three-decked for three rows.

There are two methods of bringing the different rows of holes into action—one consists in lifting the needle plate,

and the other in lifting the cylinder. The latter is preferable, for needles work best when at right angles to the hooks. By lifting or depressing the forward end of a needle while leaving its rear end stationary one set of wires will be inclined to the other.

In Fig. 56 a plan for lifting a needle plate is shown: A′ is a shaft and upon it two arms B′ are fastened to support two bars C′ and the needle plate G. A handle E′ and a notched plate F′ are employed to move G and the needles up or down. If a card has three rows of holes, the needles are opposite the middle row when the handle E′ is in the centre notch of F′. If E′ be moved to the notch on the right the top row will be used, and if moved to the notch on the left the bottom row will act upon the needles.

A needle plate G may be moved automatically by connecting the arms C′ to two horizontal levers, each furnished with an antifriction bowl. Beneath these bowls two chains are passed round two chain wheels, which are set-screwed upon a shaft. A ratchet wheel on the same shaft is driven by a pawl mounted in an arm attached to a second shaft, and another arm upon the second shaft is connected to a spare hook in the dobby. At each revolution of the pattern cards this hook is lifted, and the pawl drives the ratchet one tooth, and moves the chains one link, forward. A deep link puts one pattern in action, a shallow link the other.

For cross-bordered fabrics the chief objection to this plan is that both patterns must repeat upon the same number of picks, or one must be a measure of the other.

In Fig. 60 adjusting parts are shown attached to the cylinder instead of the needle plate: A is the shaft, B an arm, C the cylinder batten, D the cylinder, E the setting handle, and F the retaining plate.

The cylinder motion of a dobby has been referred to as horizontal, but some cylinders swing about a centre while others only rotate. The parts of a swinging

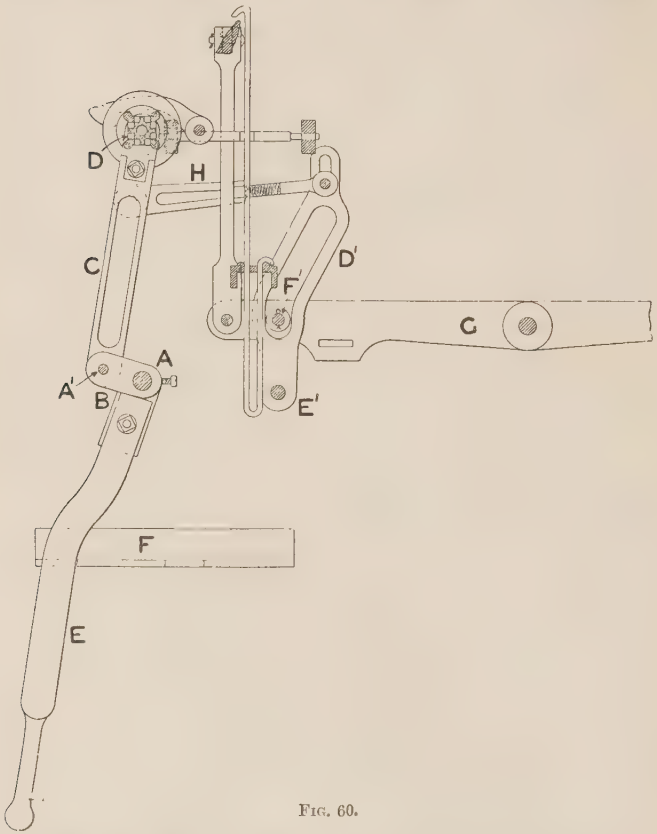


Fig. 60.

cylinder are given in Fig. 60. A shaft A′ is placed near the foot of the machine and carries two uprights C, in the upper ends of which the cylinder D and its bearings are

secured. An arm D′ swings freely upon a pin E′ as a bowl F′, upon the lifting lever G, moves up and down the curved slot in D′. A connecting rod H couples D′ and C, and conveys the motion of the former to the latter.

Other things being equal, a swinging motion is inferior to a horizontal one, because it moves in the arc of a circle and the needle points do not face the centres of the holes in the cards except when the cylinder arms are vertical, whereas a horizontal motion constantly holds the hole centres opposite the needle points.

A cylinder to which only a rotary motion is given requires a series of flat springs to cover the needle points, and lags are used instead of cards. In Fig. 61 the springs A are $\frac{1}{4}''$ wide; they form an almost continuous line across the machine, and so give a comparatively large surface for each peg to act on; it would otherwise be impossible to ensure perfect working, as a peg would slip off its needle. The springs are screwed upon a rail B, and slightly bent outward by a rod C. Each needle D is riveted to a separate spring, and, when the barrel E is turned, a cylindrical peg in a lag presses back A and D, and forces a hook F over the griffe G. The barrel E is rotated intermittently by centring a catch upon the griffe block. Each time the griffe rises the barrel makes $\frac{1}{8}$th of a revolution.

In dobbies of the types illustrated by Figs. 56 to 60 fresh cards are required for each pattern, and they form the most expensive item in connection with these machines. Inventors have endeavoured in many ways to reduce the cost of using card dobbies; for example, continuous sheets of perforated paper have been tried; also sheets of wire gauze, and canvas cloth, in which some of the perforations were stopped with varnish, or other material capable of resisting the tendency of needles to break or puncture it;

but they found little favour. Lags are often preferred to cards, because pegs can be readjusted for a new pattern.

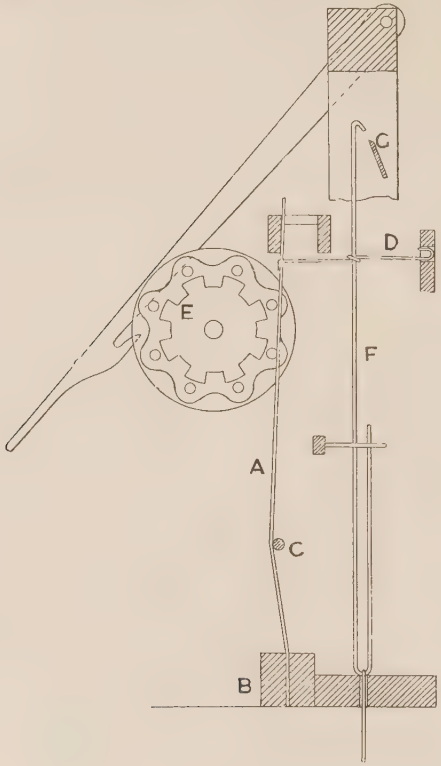


Fig. 61.

A lag is a piece of wood drilled with holes that coincide with the needles. Two staples are driven into each edge of a lag and all are linked together with rings to form a chain. Wooden pegs are then pressed into pre-determined holes to serve as risers or sinkers.

Lags are altered in form to suit the make of dobby they are intended to be used with. Some are drilled with a single line of holes, while others have two lines of holes. In the latter the holes forming the second row are midway between those of the first row. Each lag governs two sheds, thereby reducing the length of lattice required for a given pattern. Pegs for all double and many single rowed lags are cylindrical in form, and are usually about $\frac{3}{4}''$ long by $\frac{1}{8}''$ in diameter (see Fig. 62, No. 1); but as such thin wood is liable to break when working, metal in various

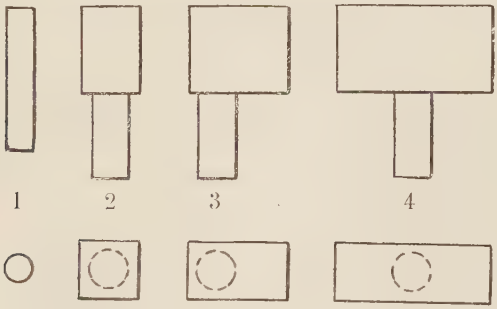


Fig. 62.

shapes, also split metal tubes pressed over wooden pegs, have been tried as substitutes, with, however, only partial success. Other pegs for single pick lags have a round shank and an oblong head; needles may then be dispensed with if the pegs are pressed against the hooks to push them on or off the griffe. A peg similar to No. 1 selects a shaft to lift, while pegs 2, 3, 4 allow shafts to remain stationary. No. 2 shows a peg for a single hook, No. 3 operates two, and No. 4 operates three hooks. A single peg is approximately $\frac{1}{3}''$ across the head and a three-hook peg $1''$; all are about $\frac{5}{16}''$ thick. Large pegs such as 3 and

4 when employed reduce the time taken to prepare a set of lags.

Dobbies are known as right and left handed; the distinction arises from the position of the starting handle of a

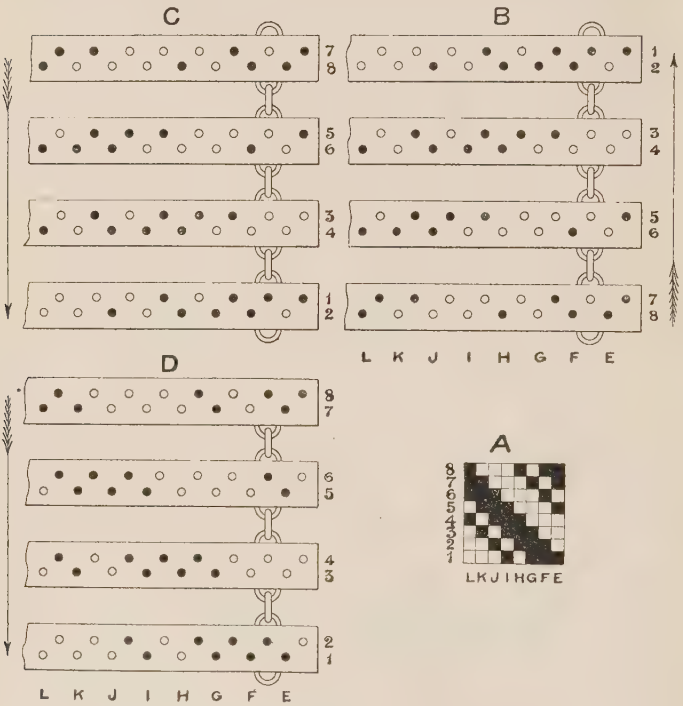


Fig. 63.

loom. If, when a weaver faces the fabric, this handle is to the right, the machine is said to be right-handed, but is fitted over the left-hand end of the framework. When the handle is on the left, the machine is left-handed and is over the right-hand end of the framework. The position

of a dobby makes a difference in pegging a pattern, as will be seen by referring to Fig. 63, in which A is a design, B, C, D are lags, with the solid circles representing pegs inserted for pattern A. Of these, B is for a right-handed machine; C for a left-handed machine of the old style, and D for a left-handed machine of the new style. The letters on A refer to shafts and the numbers to picks. With lags placed as above, the front heald shaft is always governed by the first peg in each row of holes, on the right of a lag. At one time all dobbies using this type of lag were constructed for the bottom griffe to move out for the first pick; the effect of which was to reverse the direction of rotation in the lag barrel of a left-, as compared with that of a right-handed machine, and hence the necessity for varying the pegging. For a right-handed dobby, the top row of holes in the uppermost lag of B is the first pick. In the old style of left-handed machine, the first pick is pegged in the top row of holes in the bottom lag of C. In the new style of left-handed machine the first pick is pegged in the bottom row of holes in the lowest lag of D. Each arrow indicates the direction in which the lags will rotate. A few left-handed machines of the old style are also fitted with a pulling, instead of a pushing catch, and then the lags, whether for right- or left-handed dobbies, are pegged alike.

The Centre Shed Dobby

The centre shed dobby was introduced to expedite shedding. It is now chiefly used when the nature of the fabric to be made precludes high speeds, and when closed shedding is preferable to open shedding, as in gauzes. For such work, and for speeds of from 150 to 160 picks per

minute, it is well adapted, but at higher speeds it ceases to be reliable. Speed is limited by the striking capacity of the cylinder, for a high speed tends to throw the cards off the cylinder; the needles puncture the cards, and the short time available for selecting rising and falling hooks tends to defective shedding.

The essential parts of a centre shed dobby are illustrated in Fig. 64, where a griffe A swings upon a pin at A′, and a grid B, upon which the hooks rest, swings upon a pin B′.

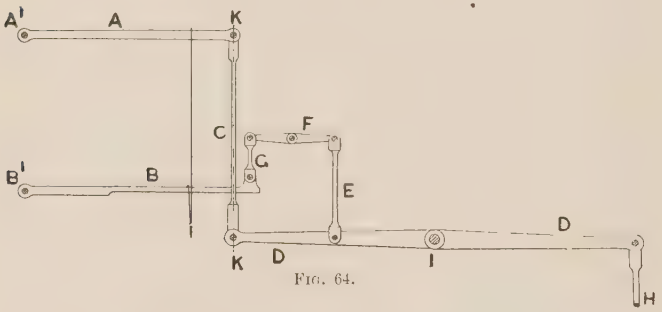


FIG. 64.

Both A and B are operated simultaneously in opposite directions by a crank, by links, and levers, in the following manner:—A crank on the top shaft of the loom vibrates a rod H, the latter is attached to a lever D, and D is fulcrumed at I, then a link C couples D to A. A second link E unites D with a lever F, which swings on a stud bolted in the framing. At the opposite end of F a link G connects F with the grid B. Since the motion of D is reversed by E, F, G, the grid B descends as the griffe A ascends. As a sequence all hooks taken up by A lift shafts to form the top shed, while those missed by A sink with B to the bottom shed. Simultaneous up and down movements of the heald shafts reduce the time occupied

in making changes to approximately half that required for a single-lift machine. In a loom the lever D is at right angles to A, B, but in the drawing, parts D, E, F, G, H have been turned on the dotted line K, to show the working clearly. With the parts arranged as here shown, the rise of A will exceed the fall of B, but slight alterations in the levers and links would produce equality of movement.

The card cylinder is frequently "decked" and swings, as in Fig. 60. Ordinary needles are employed, but each has a collar soldered upon it for one end of a loosely threaded spiral spring to impinge against; the opposite end of the spring bears upon the back plate.

Double-Lift Dobbies

In respect to steady working at high speeds, double-lift dobbies possess advantages over those that form a centre shed, because a card, or lag barrel, only actuates a set of hooks once for two revolutions of the crank shaft. The time for selecting a fresh series of hooks is thus doubled; the cards are not perforated by the needles, nor are the pegs broken to the same extent, and certainty of action increases with the time available for making changes. Instead of rising to the centre and sinking again for the next pick, a shaft can remain stationary at the bottom for an indefinite period. By this means the warp is kept steadier and less strain is put upon it. For gauze textures, however, the only advantage a double-lift machine possesses is a higher speed, as an open or semi-open shed must be partially converted into a closed one by the application of parts known as "shakers." See pp. 258 to 261.

The Blackburn Dobby

The Blackburn double-lift dobby has been developed from the single-lift type, and it possesses fewer distinctive features than most machines of this class. In many essentials it resembles a double-lift double-cylinder Jacquard, but it has been modified to meet the special requirements of a dobby. Some of these machines contain 100 hooks, in which event they are capable of actuating 50 double jacks; but the parts are then too lightly constructed for moving heald shafts.

The machine is placed above one end of a loom so that tappets fixed at the centre of the bottom shaft may govern ordinary healds. Its central feature consists of hooks placed in two lines and operated by pegs without the aid of needles or other intermediary parts. In 1875 Yates and Brierley secured an extra pair of tappets upon the bottom shaft and allowed two treadles to rest upon them; to these they attached long connecting rods by studs. After passing through the warp, the rods were respectively made fast to griffe bars which were fulcrumed to give a varying lift. For a straight lift the griffe treadles are below the tappets, and the connecting rods are attached to the treadles and to adjusting pieces pendent for the griffes. Both griffes are then united by bolting one strap to an end of each, and a similar strap to the opposite ends; the straps are in turn bolted upon the surfaces of two pulleys, which are mounted upon a horizontal shaft placed parallel with, but above, the hooks. Hence, if one rod is depressed, the griffe shaft and pulleys oscillate and give equal but opposite movements to the griffes. The lag barrels are driven from one end of the tappet shaft by a crank and connecting rod; these rock

a lever and thus give a sliding motion to the barrels. Rotation is derived from a pulling pawl that rests upon a ratchet, keyed upon one of the barrel shafts. At each oscillation of the lever the pawl pulls one barrel through $\frac{1}{8}$ of a revolution, and the other is moved an equal distance by spur wheels fitted upon the barrel shafts.

Two tappets, one crank, and three connecting rods are thus employed to convey motion to all parts of this dobby, and since two of the rods go through the warp, it is by no

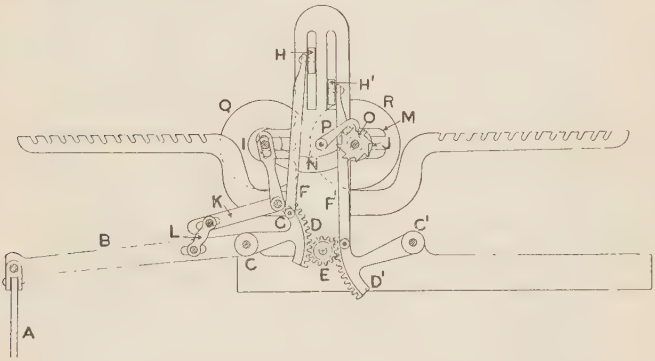


FIG. 65.

means an ideal arrangement. If the parts are connected, as in Figs. 65 and 66, a single crank and rod will suffice: the driving parts will be outside the loom framing, and either a straight or an unequal lift can be given at pleasure.

This method of positive driving was invented by Ainsworth and Ainsworth in 1879. In Fig. 65 a rod A connects a crank on the bottom loom-shaft with a lever B, which swings on a centre C, and carries a toothed segment D into contact with the teeth of a wheel E. One end of a rod F is pinned upon D, at G; the other end is

secured to the griffe H. A similar segment D′ vibrates on a pin C′, and gears with the opposite side of E. This segment is likewise connected to the griffe H′ by a rod F′; therefore, as B ascends and H descends, the segment D′ receives a simultaneous but diametrically opposite movement to D, which causes H′ to rise when H falls and *vice versa*; both griffes meet in the middle and give a similar semi-open shed to that of a double-acting Jacquard.

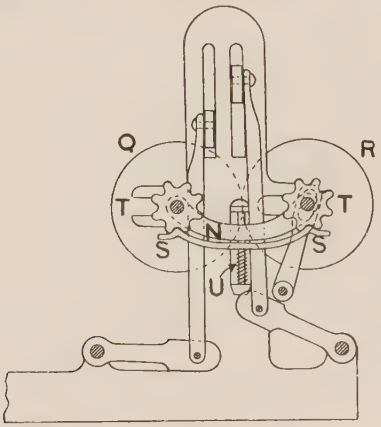


FIG. 66.

The lag barrels I, J are coupled by two curved links that form a carriage N, and move in slide bearings M. Motion derived from B is conveyed by a lever K through a link L to both barrels. The link fits upon two studs—one in B, the other in K, both permit of alterations in the throw of the barrels. A ratchet wheel O, with eight teeth, is keyed upon the rear end of the shaft of barrel J, and a pawl P, centred upon a stud in the framing, rests upon O. Two equal wheels Q, R are screwed upon the forward ends of I, J, to connect and turn both barrels inwards at the

same instant. The barrels are kept steady by a hammer consisting of a bar of metal S, Fig. 66, which is bent at two places to engage with the lower notches of two octagonal star wheels T, that adjoin the wheels Q, R. The bar S is retained in contact with T, T by threading a spiral spring U upon its shank; so that the lower end of U shall impinge against a holding bracket, and its upper end against the bar S.

The legs of a series of wire hooks, V, Fig. 67, are

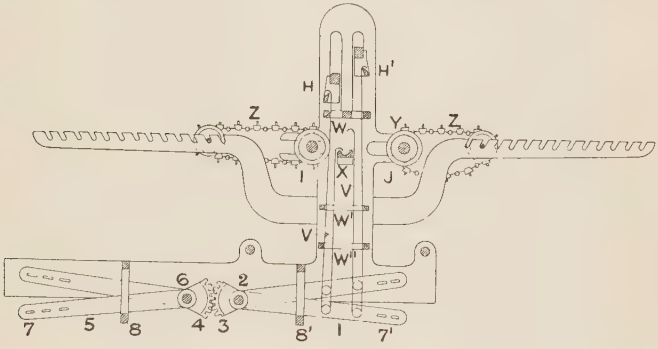


FIG. 67.

respectively 21″ and 15″ long; they are placed, back to back, in two parallel rows. All are retained in a vertical position by three grids W, W′, W″, and by a rest X, which supports the short legs of V. When unmoved by pegs the vertical hooks are caught by the rising and falling griffes H, H′.

The lattice Z is equally divided—one half is pegged for odd picks, the other for even ones; they are passed round and revolve with the barrels I, J. The pegs Y force the hooks V from the griffes H, H′; hence a peg equals a hook left down, and an empty hole in a lag Z permits a hook to lift.

Two hooks, one in each line, are attached to jack 1, either by nipples on the jacks or by sliding a jack through the loops of both hooks. These jacks are only $\frac{3}{4}''$ to $1''$ deep by $\frac{1}{16}''$ thick, and 40 of them occupy a space of $13''$; each is fulcrumed at 2, and provided with a toothed segment 3, that gears with a similar segment 4, on a second set of jacks 5. The latter all move on a fulcrum pin 6, and connection is made with the harness at points 7, 7′. When a hook is lifted, the jacks 1, 5 move through a similar upward space; and the grids 8, 8′ prevent side movement.

If this dobby is used to weave striped and bordered goods, alternate lags are pegged to suit each pattern, and the lattices advance two lags at a time, until a change of pattern is needed; the barrels are then moved, either mechanically or manually, one lag, so that those previously idle may become operative. By another plan two barrels are fitted on each side of the machine, one above the other. Each pair carry lags for weaving a different pattern; when a change is needed one pair of barrels are put out of, and the other in, action.

This dobby is chiefly employed to ornament fabrics known as dhooties—which are plain weaves figured near one or both selvages with loosely floating coloured threads. Tappets and heald shafts are then used to weave the plain fabric, and the dobby contributes the figure by means of two Jacquard harnesses that seldom exceed $4''$ in width. Each harness is secured near one edge of the piece and is kept in tension by elastic cords, or dead weights.

The Keighley Dobby

In 1867 Messrs. Hattersley and Smith patented a dobby that is still unsurpassed for most shaft work; but extended

use revealed defective details in the original model; these caused excessive wear and tear, slipping of needle collars, difficulty in making repairs, and a lack of stability. Many of these defects were removed before the patent rights expired, others have been rectified since the machine became public property.

During the last few years this dobby has been modified in many ways to meet both special and general requirements. A sectional drawing of Ward Brothers' model is given in Fig. 68, where the hooks A, B are placed horizontally, and jointed at one end to a rocking bar C, and C is in turn supported at D′ by the upper part of a front crank-lever D. The lever D is fulcrumed at E, and connected to a heald shaft at F. A slot G is concentric with E, and receives a pin that assists to hold D in position.

Each hook A is normally held horizontal by a needle H, which is circular or square in section, and rests upon the straight and lighter end of a lever I, whose fulcrum is at J. But each hook B is supported by a similar lever I, except that I is prolonged and bent until its upper end touches the under side of B. The needles H are kept vertical by passing them through holes in the flanges of grids T, U, and the hooks A, B are held parallel by these grids. The levers I, I′ are confined by similar means. In a right-handed dobby a lever I is placed next to the front framing, but in a left-handed machine of the new type the lever I′ is the first.

Immediately below the heavy ends of I, I′ an octagonal lag barrel S is free to rotate; the pitch of the lags being equal to that of the levers I, I′, it follows that a peg will lift, and an empty hole will leave I or I′ stationary,

By lifting a lever I, or I′, where the lags act upon it, the inner end falls and removes the support from a hook,

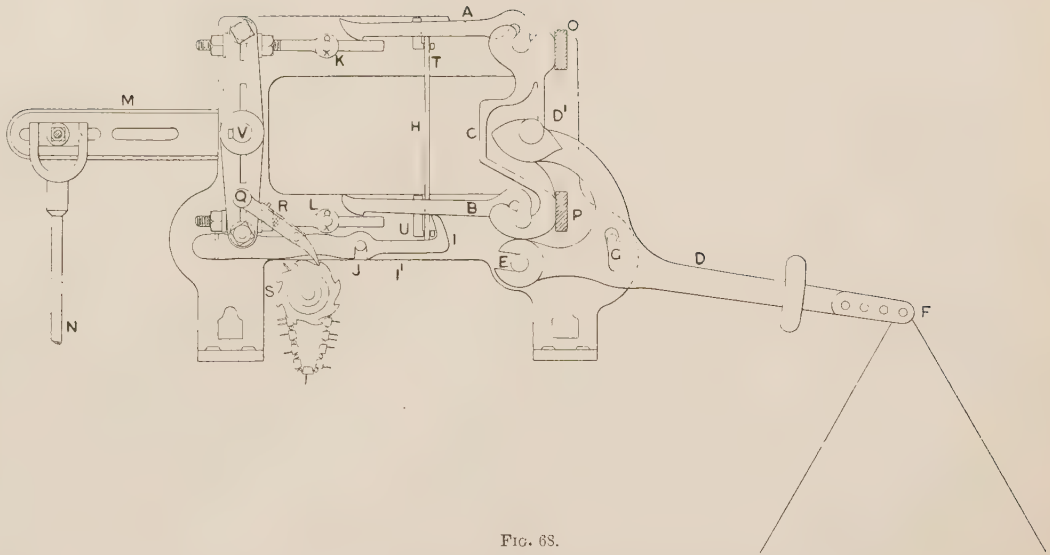


FIG. 68.

hence the outer end of A or B will sink into contact with a draw knife K or L. Both K and L slide in horizontal slots in the framing, and are connected by adjusting rods to a three-armed lever M, which is centred at V. A crank on the bottom shaft of the loom and a lifting rod N cause M to oscillate and drive K, L. When a quicker movement and a longer pause at each extremity are required, elliptical gearing is employed.

As the crank revolves, the knives K, L slide in opposite directions, and the fall of a hook A or B is timed to occur when K, L are at the extremities of their oscillations. The hooked parts of A or B will then be slightly in advance of one drawing knife. Assuming K to move out, it will take a hook A with it, pull the top of a bar C from the stop O, press its lower end against the stop P and draw D′ forward, thus lifting F, and the heald shaft, to which it is attached.

The lags being double-rowed, as shown in Fig. 63, one line of pegs acts on the levers I, the other on levers I′ simultaneously, and they, and the barrel S, remain stationary for two picks; after which S is turned $\frac{1}{8}$ of a revolution to place the next lag beneath the levers I, I′. This is accomplished by hinging a jointed pawl R upon a pin Q in the lower arm of the lever M. As that arm moves in, R engages the teeth of a ratchet wheel upon the barrel shaft and pushes it forward. A flat spring is secured to the upper part of R, it extends beyond the joint, and exerts sufficient force to turn S under normal conditions, but in case anything goes wrong with the lattice, the pawl R bends at the joint without moving the barrel. The lags and barrel are kept steady by bolting a flat spring to the framing and causing it to press upon the top of an eight-sided star wheel, which is fast upon the barrel shaft.

Each heald shaft requires one front crank lever D, one rocking bar C, two hooks A and B, one needle H, two levers I and I′, and either a peg or a hole in one lag for each lever. The machine is placed over one end of a loom so that the point F of the lever D shall be in the centre of the reed space. In this dobby a slight lateral movement accompanies each vertical movement of a heald shaft, but the machine has been modified to give a true vertical lift.

An open shed is formed, for when the knife K is at the outer end of its slot, with a hook A drawn forward, the knife L is at the inner end of the other slot, with a hook B in position for drawing. Since the inward movement of K corresponds with the outward movement of L, it follows that the centre D′, and therefore the heald shaft, will remain stationary, except in so far as changing the direction of inclination in C, and the excess of movement in K, L over that in A, B will alter it. Time and freedom for the hooks to rise and fall is provided by causing a draw knife K, or L, to move inward for a short distance after the hooks A, or B, have become stationary. But this movement combined with the swing of the balk C seldom causes a heald shaft to sink more than $\frac{1}{4}''$ to $\frac{3}{8}''$. In some machines the healds are kept stationary by removing the draw knives K, L from the three-armed lever M, and mounting them upon an extra balk, in which there are curved slots for two bowls upon the lever M to work in. The slots permit one draw-bar to remain stationary while the other moves to release its hooks and receive fresh ones.

Messrs. Butterworth and Dickinson added parts which were intended to shield pegs, similar to No. 1, Fig. 62, from injury. They caused the levers I, I′ to be lifted away from the pegs before and during rotary movement in the barrel S. But on the completion of such movement the

levers assumed their normal positions. This plan was not generally adopted on account of each peg receiving a blow when contact with the levers was restored.

W. Williamson dispensed with the levers I, I′ and the needles H, and made two sets of single pick lags, with pegs similar to Nos. 2, 3, 4, Fig. 62, to act directly upon the hooks. One set was pegged for odd picks, the other for even picks of the pattern, and each operated its own set of hooks. Both barrels were also positively driven.

In a Hattersley dobby cards may serve instead of lags as the selecting medium. When this occurs the heavy-ended levers I, I′ are replaced by two vertical rows of wire needles, which protrude about $\frac{1}{2}''$ below a needle plate and are furnished with disc-shaped heads for the hooks to rest upon. The needles in one row are approximately $3\frac{1}{2}''$ long, and they are kept vertical by passing them through holes in two plates; their discs rest upon the upper plate, and the lower hooks rest upon the discs. The needles in the other row approximate to 13″ in length and pass through holes in three plates, but are set midway between those in the first line, and upon the discs of these needles the top hooks rest. An octagonal card barrel occupies a similar position to, and takes the place of, the lag barrel S. Its office is to carry a chain of cards into contact with the lower ends of the needles. This barrel is mounted in two levers, which are rocked upon their centres by a connecting rod and an eccentric fixed upon the crank shaft of the loom. Each upward oscillation will cause a card to impinge upon the needles and lift those that face solid parts of the card. Rotary movement is given on alternate picks by a pawl and ratchet operated from the knife lever M. Unlike a lag dobby, the hooks are normally on the knives K, L, and the cards and needles must lift those out of contact

that are not to be drawn; hence the barrel, although turned once for two picks, is pressed against the needles for every pick.

Provision is made in some of these dobbies for levelling all healds before repairing broken warp. This is done by fixing a swivelling bar beneath the hooks in the top row and fitting an arm upon it which carries a pendent handle. By pulling down this handle the bar lifts all hooks out of contact with the top knife, then, on the next outward movement of that knife, no hooks will be drawn.

Messrs. Hattersley recognised that when the draw knives K, L move in parallel slots the rear end of each hook falls into a lower plane and its head is liable to be thrown up far enough to permit it to slip from a knife. In order to remedy this they now make the slots to converge, so that as the knives move outward a hook-head from the top row will be drawn downward, and one from the bottom row upward, as in Fig. 75.

Cross-Border Dobbies

With a dobby of the Hattersley type difficulty was experienced in weaving cross-bordered fabrics, such as handkerchiefs and towels, on account of the lag space being limited. Many attempts were, however, made to weave such articles, as, for example, by pegging one pattern on alternate lags and another pattern on intervening lags, then giving the barrel a movement of two lags instead of one, until a change became necessary. The barrel was then moved a single lag to bring the second pattern into operation. As a rule the weaver was called upon to effect this change. But measuring chains, provided at suitable intervals with deep links, have been driven from the taking-up roller. Each

deep link dislocated the driving gear and stopped the loom in time for a change of pattern, when the weaver turned the lag barrel one tooth. Similar measuring motions have also been made to effect such changes automatically, but most of them lacked precision, and defects in the pattern were frequent at the changes.

In the year 1885 Ward Brothers, and at later dates other machinists, added parts which change from pattern to pattern with ease and certainty. Fig. 69 shows the method adopted by Messrs. Lupton and Place. It consists in the use of two lag barrels S, S′, one to carry the border lags, the other those for the body. Both barrels are mounted in a pair of arms 1, which are set-screwed upon a rocking shaft 2. A third arm 3 is also fixed upon this shaft, and terminates in a stud for the support of a casting 4 with a horn at each end. 4 is loosely mounted, and as the lever M rocks, a stud 5, fitted upon M, may make contact with either horn of 4, and cause the barrel shaft 2 and the barrels S, S′ to rock simultaneously. Whenever one barrel is moved away from the levers I, I′, the other barrel is taken into contact with an additional set I″, I‴. The precise means adopted to rock the barrels S, S′ largely determines the value of a device of this kind. Here a short barrel 6 is mounted upon a shaft 7; it is behind the rear frame-work, and beneath the lower line of hooks B. Each lag on 6 is provided with, or left without, a single peg. A lever 8, fulcrumed at 9, rests upon the lags, and its outer end is slotted to receive a stud in the double horn 4. When 8 is lifted by a peg, the outside pattern barrel S′ engages with the levers I″, I‴. When 8 is undisturbed, the inside pattern barrel S is in action.

The barrel 6 moves once only for each revolution of

either the border or body lags, for a peg in each lattice as S, S′ puts in action the otherwise idle back balk C; at such times C impinges upon a stud in a lever 10, which is fulcrumed at the top and carries a pawl 12 at the base to drive a ratchet upon the barrel 6. The lever 10 is normally held back by a spiral spring 11. If the last lag brought into position by 6 is similar to the preceding one no change is effected in the barrels S, S′, but if one is pegged and the other is without a peg a change will occur in S, S′. Each set of pattern lags can therefore rotate any number of times without a change of weave, and there is no necessity for a border repeat to equal, or be a measure of a centre repeat.

The levers I, I′ are united to a corresponding set I″, I‴, either by forking the light ends of one set and pushing those of the other set between the prongs, as at 13; or the ends of one set may simply overlap those of the other set. Both plans will cause a peg in a lag on S or S′ to engage a hook A or B with a knife K or L. Two pawls, R, R′, are mounted upon a stud in the knife lever M, and each may drive its own barrel whenever rotary movement is necessary. But one barrel turns inward, the other outward, and one set of lags must be pegged as at B, the other as at C, Fig. 63. The centre of the working barrel is always higher than the centre of the shaft 2, and two flat locking springs 14, Fig. 69, bear upon the cam-shaped terminals of the outer arms 1. In lieu of the foregoing, a cam may be mounted upon a separate shaft to rock the barrels positively in either direction, in which event the cam locks as well as rocks. Both devices prevent a driving pawl R or R′ from vibrating the working barrel.

Curved brackets, fitted to the front framework, limit the upward movement of a barrel. There is the usual

FIG. 60.

hand adjusting wheel on the forward end of each barrel shaft S, S′, and also one on shaft 7, to facilitate pick-finding.

In a recent type of cross-border dobby, Fig. 70, introduced by Messrs. Ward Brothers, the rocking shaft is dispensed with and the lattice barrels work in fixed bearings. In its usual form two pattern barrels S and S′ are used, but for some special designs of cloth, where the use of two pattern barrels only would necessitate long chains of lattices, the three-barrel motion illustrated has been introduced.

Whereas in other motions a chain of lattices has been blanked or rendered inoperative by swinging the lattice barrel away from its feelers, or by lifting the feelers away from the lattices, in this motion the result is obtained by stopping a lattice barrel with the space between two lattices directly opposite the feelers, as at S′ and S″. Each barrel is provided with two ratchet wheels R, R′, and each wheel is provided with a driving pawl P or P′, the pawls for the two ratchets of each barrel being on the same stud. A set of three-holed measuring lattices M acting on three levers L, L′, L″ determines which of the three pattern barrels S, S′, or S″ is operative. A blank under any lever, say L, lowers the corresponding outer pawl P into contact with the outer and smaller ratchet wheel R on the pattern barrel S, and that barrel is driven by the small ratchet wheel, the back pawl P′ being inoperative as it is raced by its large ratchet wheel. The two barrels S′ and S″ are meantime inoperative, their outer driving pawls P being lifted out of contact with the small ratchet wheels by pegs in the measuring lattice M acting on the levers L′, L″. These two barrels are pushed forward by their inner pawls P′ and large ratchet wheels R′ till the space between two lattices is opposite the feelers and they remain in that position until a change is required, as determined by the measuring

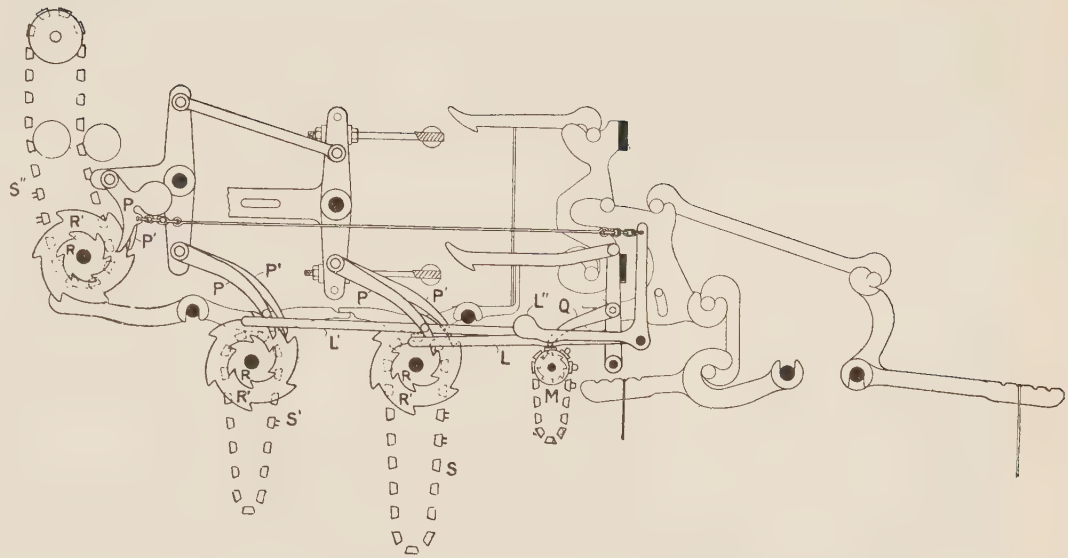


FIG. 70.

lattice M. M is driven by a ratchet and pawl Q from a rocking lever controlled by the first bottom hook of the dobby. M is moved forward one lattice at the end of the repeat of a pattern, but whether a change of pattern takes place or not depends on whether the lattice brought under the levers L, L′, L″ differs from its predecessor or not. To change, for example, from pattern barrel S to S′, a peg under lever L would lift the outer pawl P of barrel S out of action. S would then be pushed over to its inoperative position by its pawl P′ acting on the large ratchet wheel; the pawl P′ then rides idly on the same tooth of the large ratchet wheel so long as S remains inoperative.

Simultaneously with the above action a blank under lever L lowers the outer pawl P of barrel S′ into contact with the smaller ratchet; P completes its stroke and places the first lattice of pattern S′ into work. A peg under lever L″ keeps S″ still inoperative.

In this way any number of repeats can be made from any pattern, and a change can easily be made from any one to any other. All pattern barrels rotate in the same direction, and thus there is only one hand for pegging purposes. A special form of star wheel, having six large and six small slides arranged alternately, so that the barrels are held steadily in either the usual or the inoperative position, is fitted to each pattern barrel. Fig. 70 also illustrates Messrs. Ward Brothers' latest improvements in double jack dobbies, the teeth in the jacks being dispensed with and each jack lifted by its own link.

The Burnley Dobby

During the years 1888 to 1893 Messrs. Lupton and Place developed a dobby of original design and action.

The framework is triangular in shape, and supports at its apex a shaft A, Fig. 71. This shaft carries two levers B, and also two fulcrum pins C, D for a series of cast-iron arms E, F.

The working parts are actuated by a crank and connecting rod from the bottom shaft of the loom. The pendent arms E, F are vibrated alternately and give motion to the heald shafts through jack levers G. These levers are fulcrumed at H, and bent almost at right angles to place their notched ends J in line with E, F, while their outer ends are united by links L to the heald leavers I.

Two pendent arms E, F serve, instead of draw hooks, to lift one shaft. This occurs whenever the lower end of E or F is pushed by a peg O over one of the notches J. On the next oscillation of the levers B, the bent end of a jack lever is forced down by either E or F, and the levers I, I in rising carry a shaft up with them.

To protect the pegs from injury a flat spring K is fixed upon a stationary bar T, T, to face each arm, E, F, and the lower end of each spring is passed through a slotted slide U, which also governs a pendant. Immediately an unpegged portion of a lag faces a spring, the latter moves out with its slide and draws a pendant out of contact with the notched end of J. But when a peg O faces a spring, that spring gives way, and, at the proper moment, carries back its slide and pendant until the latter is over a notch in J.

A lattice is made in two parts; odd picks from the design form one chain, and even picks the other. The chains are passed round separate octagonal barrels M, N, and an intermittent rotary motion is imparted to them by a pushing catch P, centred upon an arm Q, on the top shaft A. Consequently P, Q partake of the rocking of A, and as P acts upon a ratchet wheel on the shaft of N, the barrels

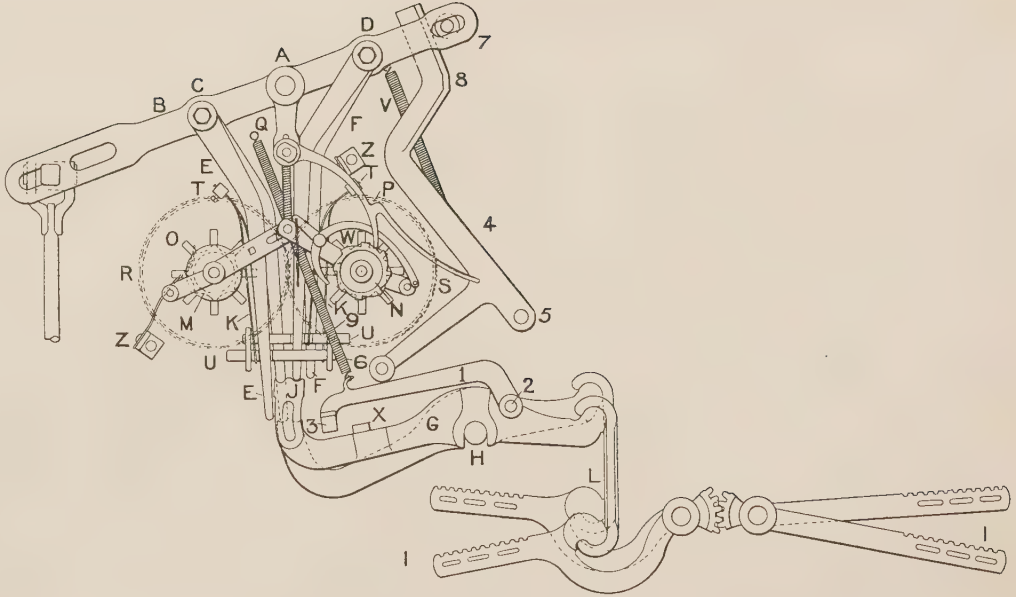


Fig. 71.

are turned for alternate picks. Both lag barrels M, N are connected by spur wheels R, S, hence both are moved simultaneously.

A reversing motion is applied to the dobby to assist a weaver to find the proper starting-place after unweaving, or after the weft has broken. A lever W has for its fulcrum the shaft of barrel N, and mounted upon W is a pawl that may engage the inside of an inverted ratchet wheel on the shaft of N. By drawing down a cord attached to W, the pawl P is lifted, and the lever W reverses both barrels, while the loom is stationary.

A cross-bar X limits the upward movement of the jack levers G; it can be fixed nearer to, or farther from, the fulcra of G, and so regulate the depth of shed, but when parallel to H the lift of all the shafts is equal. An unequal lift will be obtained by fixing the forward end of X farther from H than its rear end, for the front notches J will thereby be pushed farther down, and the pendants E, F will move through a greater space before disturbing the front healds. A stout spiral spring V is attached to the inner end of B, to balance the lifting tackle, and two flat springs Z bear upon star wheels to steady the barrels M, N.

The chief merits of the machine are that the parts are easily detachable, and cast iron is applied to resist a compressing force, instead of, as in most dobbies, a tensile force.

Positive Closed Shed Dobby

For heavy work a positive shedding motion is the best type to use, provided other parts of a loom are equally positive in action; but there are many looms which limit the usefulness of such a dobby. For instance, if used with a cone-pick, multiple shuttle-box loom, the advantage

of being able to work the loom and dobby backwards together is neutralised by the picking motion ejecting the shuttles from the boxes, and probably also by the box-indicating mechanism continuing to turn forward. Such defects are, however, due to the picking and box motions rather than to the dobby.

In one make of positive dobby a spur wheel A, Fig. 72, is secured upon the bottom loom-shaft to gear with a wheel B, which is compounded with a bevel C. Both B and C turn loosely upon a stud D, fixed in a cross rail. The bevel C engages a similar wheel at the foot of an upright shaft E, and a third wheel F, near the top of E, drives a bevel G, on the dobby shaft. This shaft carries two pairs of eccentrics H; each pair is coupled to place the large side of one at the top when the large side of the other is at the bottom. Two rods, I, I, pass from two eccentrics to the griffe J, and corresponding rods from the remaining pair of eccentrics are connected to the bottom bar K. Hence, as the eccentrics turn, J and K move in opposite directions.

In section the hooks L are $\frac{7}{8}''$ by $\frac{1}{4}''$. They are formed with a catch at the top, and rest upon the bar K in two lines, with the catches facing each other, so that the front line when vertical will miss a blade in the griffe J, while the back line will be over a second blade of J. When in action the front row pull the heald shafts down, and the back row lift them. This is done as follows: From every hook in the front row a rod M passes down to a lever N, which is centred in the middle and has a cord tied to its opposite end, and also to a bottom heald shaft 6. From every hook in the back row a rod O is taken to a lever P, and P is connected by toothed segments at T to a second lever Q. These levers are respectively fulcrumed at R, S.

Cords 3, 4 unite P, Q with a top shaft 5. A lever N reverses the motion of a hook L, and sinks a shaft, but the levers P, Q act in unison with a hook and provide a straight lift.

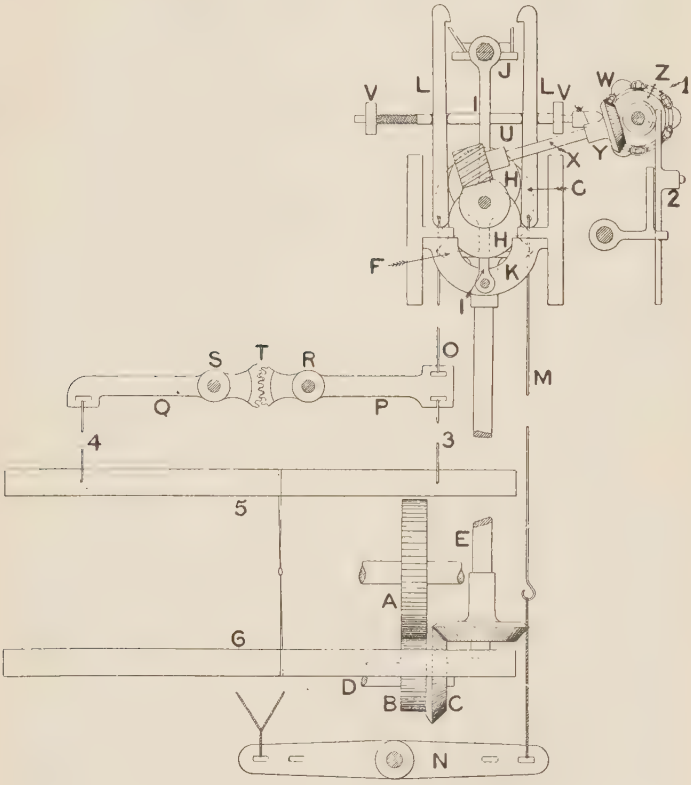


FIG. 72.

Inside the machine framing the needles U are almost square in section, but they are rounded at each end to work in the holes of two needle plates V. Each needle is slotted at two places to receive two hooks L, and each has a semi-

circular sheath for the lags W to operate. The latter are made of iron, and the pegs are rounded on the top and so disposed that consecutive needles are moved by alternate pegs for any length of time, but the disused set can instantly become active by pushing them endwise into range with the needles, and, by so doing, a new pattern is obtained. A chain of bowls and collars, similar to those of an oscillating tappet, may be substituted for metal lags.

A continuous rotary motion is given to the lag barrel 1, by driving an inclined shaft X from the dobby shaft by a double worm and a worm wheel; a bevel Y on X also engages with a bevel Z on the shaft of 1. A fast boss on the barrel shaft has a ring groove cut in it, and the wheel Z is loosely fitted in a keyway on the shaft of 1, to permit of a lateral movement in both the lags W and the barrel 1, so that the idle set of pegs shall slide opposite the needles U whenever the position of lever 2 is altered.

The Knowles Positive Open Shed Dobby

The Knowles dobby, as made by Messrs. Hutchinson and Hollingworth, is original in construction and positive in action; it forms an open shed, gives a straight lift to the shafts, and governs the shedding, the picking, the shuttle boxes, and the taking-up motions; it also contains a levelling apparatus for placing all the healds in one line before drawing-in broken threads; and the dobby, and all it controls, can be worked backwards manually by turning a wheel.

Movement is derived from one end of the crank shaft by gearing a pinion A, Fig. 73, with a stud wheel B. The wheel B is compounded with a bevel C to drive a similar wheel D, situated at the base of an upright shaft E. The

wheel D, together with the parts G′, F, form a clutch for detaching the driving when movement in the dobby is to be reversed. By operating a lever the top piece F will rise to open or sink to close the clutch. Of the three parts, F and D are loose upon E, but G′ is a hoop which is placed close to D, and fastened to the shaft E. A hole is drilled through G′ and into the upper part of D, to receive a stud from the underside of the movable piece F. This stud is long enough to pass through the hoop G′ and enter D when the clutch is closed, but when the clutch is open the stud is withdrawn from D and the dobby stops. An arrangement by which contact between F and D can only be made when the slay occupies one position is essential, or the sheds would open and close at the wrong time. Instead of a manually controlled clutch, a cup, formed in the top of D, may have a cam groove of gradually increasing depth, cut to receive a freely fitting pin that passes through G′. When the loom is started this pin travels in the groove until the deepest end is reached, when shaft E begins to rotate. At the same instant the weighted end of a catch swings outward and the catch, by entering a notch in G′, locks the pin in position. So soon as the loom stops, the catch automatically falls out of the notch and the dobby is free to be turned backward.

Two bevel wheels H, I are fitted upon the shaft E and drive similar wheels J, K that are fast upon the lower and upper segment cylinders L, M. The wheel H drives from the top of J, and I from the bottom of K, thus causing one to revolve in an opposite direction to the other. The cylinders L, M take the place of griffe bars in ordinary dobbies, and lift and sink the shafts by means of a series of teeth that extend about half-way round each. Their teeth act upon the gears G, the vibrating levers N, and the

connecting bars R, Fig. 74. These three parts are fastened together to form one piece. A vibrating lever N is made

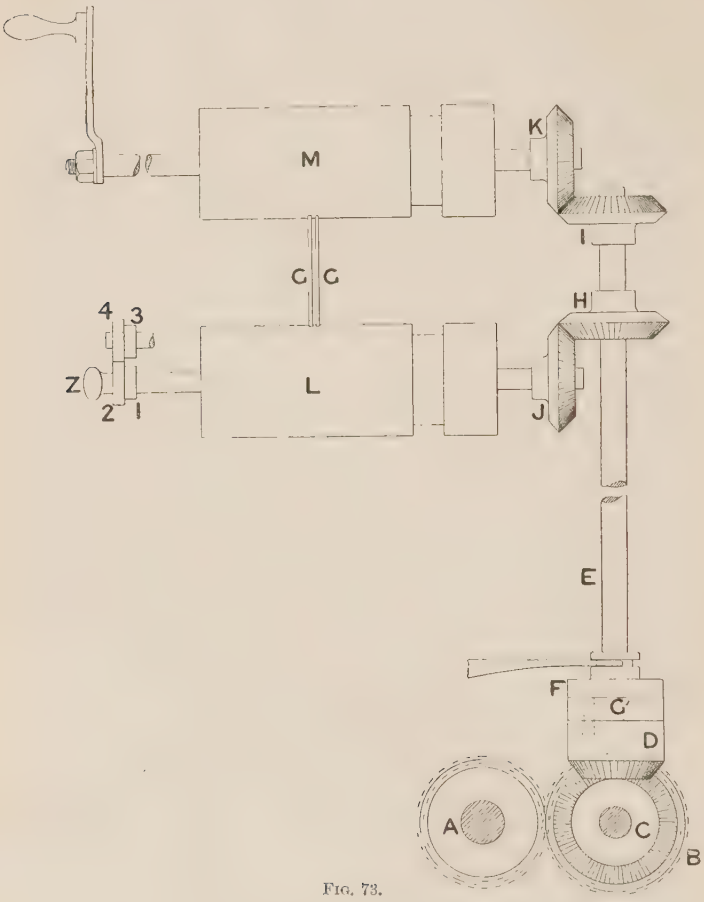


FIG. 73.

from two thin metal plates which are riveted together at different points, and kept apart at others by strips of metal

to form a fork. N is centred at O, and rests at P upon a pattern chain which is built up by threading rollers and bushes upon spindles as for an oscillating tappet. Each roller will lift, and each bush will allow a lever N to fall, therefore a vibrating lever equals a needle in other dobbies.

A gear G does duty for a hook; it is a toothed wheel $\frac{1}{8}''$ thick by $5\frac{1}{4}''$ in diameter, from which a tooth is removed at one point, and three or four teeth are removed exactly opposite the first gap. This wheel is passed between the plates of N, where it is supported by, and turns freely upon, a pin. The movement of a gear G is limited by a steadying pin in N entering a semicircular slot in G.

A connecting bar R conveys motion from a gear to a harness jack S. Two metal plates are also used in the construction of R; they are connected in the middle by rivets, but are separated to form forks at each end. A gear G is placed inside one fork, and the rivet which unites G, R serves as a crank pin, for G will be moved from one dead centre to another, and in so doing will cause R to rock. The opposite end of R is notched and hooked upon a nipple in the cranked harness jack S. From the arm U, rod and strap connections pass over guide pulleys to a top heald shaft, and from the arm V, similar connections pass under guide pulleys to a bottom shaft; hence, as a jack S oscillates on its centre T, each forward movement of the arm U will lift, and each upward movement of V will sink a shaft.

A vibrating lever N, a gear G, a connector R, and a harness jack S, together with bowls, bushes, and connections, are required for each heald shaft, and these parts are so placed that fifteen gears occupy a horizontal space of 8 inches.

The levelling apparatus consists of a flat bar X, which is furnished with a handle at one end. X is placed at right angles to and immediately below the vibrator levers N, and

it has two diagonal slots for the reception of fixed studs. By pulling the bar forward it slides, upon the studs, up two inclined planes and lifts all the levers N, to clear the gears G, from the cylinder L; then at the next revolution M will engage all gears that have the small gap uppermost, and cause them to make half a revolution. Once the large gaps are at the top, all the heald shafts will be lifted, and they will remain up until the bar X is restored to its normal position. The chain barrel Y is driven by a train of five wheels, and can be stopped, moved forward, or backward at pleasure by operating a clutch Z, Fig. 73. Thus, if Z be half opened, the wheels 1 and 2 are loosened upon L, and the barrel Y becomes stationary. If Z is closed, the wheel 1 drives the wheel 5, Fig. 74, direct, and turns the barrel forward; but when Z is fully open, the wheel 1 is released from, and 2 is fastened upon, the shaft of L. The stud wheels 4, 3, being compounded, will be driven by 2, and since 1 and 3 both engage with the wheel 5, it follows that 2 will drive 4, and 3 will drive 5 in the opposite direction to that when 1 is the driver.

Instead of the clutch described above, the cylinder M may be loose upon its shaft and that shaft be lengthened to receive a spur wheel at the front, and a loosely mounted bevel, similar to K, at the back. Both bevels gear with I on the upright shaft E, Fig. 73. The bevel K is fixed upon the boss of M and drives continually in one direction. Between these bevels a hoop, provided with a ring groove for a lever to fit in, and a projection at either end to serve as a clutch, may slide in a keyway cut in the shaft of M. Each bevel has a recess formed in its boss for the reception of a projection on the hoop. When this hoop engages the bevel K the chain barrel Y turns in its normal direction. But when the boss engages the loose bevel, the shaft of M

rotates in one direction, while the barrel continues to turn normally; the taking-up motion is also reversed with the chain barrel.

The driving gear found between the cylinder M and the

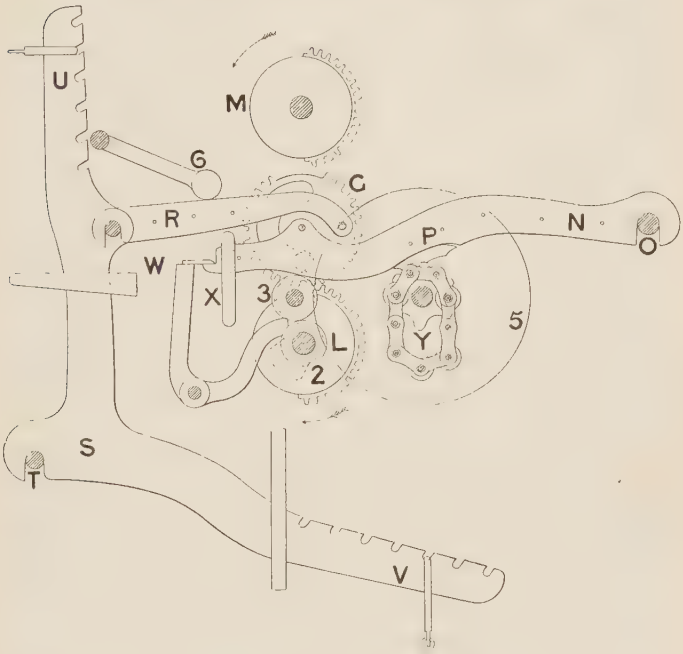


FIG. 74.

chain barrel Y may also differ from that previously described. Thus, a wheel on the shaft of M drives the largest of a pair of compounded wheels, and the smallest drives the barrel wheel 5. But the wheel 5 is now a star wheel with six notches, and between the notches it is furnished with ordinary teeth. The largest compounded wheel

carries a stud which engages the notches in 5 in order to accelerate the removal from, and replacement of bowls and bushes beneath, the vibrating levers N. The smallest compounded wheel has three teeth removed facing the stud in the other wheel, so that when the stud drives the wheel will be inoperative, and when the stud is inoperative the wheel will drive.

While the gears are turning, all the vibrating levers N are locked in position by mounting a knife W on arms that project from a shaft which is rocked by a cam secured to the bottom cylinder shaft. This cam is shown in dotted lines to be behind the wheel 2; it thrusts the knife between the lifted and depressed ends of all levers N immediately before the gears begin to move, and a weight 6 rests upon the lifted vibrators to assist in steadying their movement. Instead of a single weight 6, each vibrator may be steadied independently by the action of a bar and spring.

A bowl acts through a vibrator lever N to lift a gear G into contact with the teeth of the top cylinder M; then, provided the small gap of G is uppermost, G makes half a revolution and lifts a shaft, but if the large gap is on the top, there is sufficient room for M to pass without touching G. As a consequence, a shaft can remain up for two or more picks in succession. A bush permits a gear to drop into contact with the bottom cylinder L, and if the small gap of G is at the bottom, G will be turned half-way round, but in an opposite direction, and a shaft will sink; if the large gap is below, G will remain stationary.

When a heald shaft is in a state of rest, the crank pin used for riveting the gear and connecting lever together is in the same horizontal plane as the centre of the gear; hence movement is from one dead centre to another, and a

shaft begins to rise or fall slowly, but increases in velocity to the centre, and from that point to the end of its movement a decrease takes place proportionate to the increase.

When hairy yarn is used it is sometimes necessary to move one portion of the warp slightly in advance of another. This may be accomplished by causing the teeth on the cylinders L, M to diverge slightly from each axis. Or, one shed may close before another opens if one cylinder bevel, J, K, is set a few teeth in advance of the other.

The Hattersley Positive Dobby

Messrs. Hattersley have made their dobby positive in action by attaching to a balk C, Fig. 75, a cranked heald lever D, D′, and by using over and under connections essentially similar to those of the Knowles dobby. Each lag S′ is furnished with metal pegs, but only serves for a single pick; this necessitates important modifications in both needles and hooks. The needles H are oblong in section, and have a lip H′ formed upon them to support a hook B in the bottom line, but a corresponding hook A in the top line is supported by the same needle in the usual manner. A peg in a lag S′ will, therefore, lower two hooks simultaneously, and the next knife K, or L, to move outward will take one of them. Each hook is provided with a lower and an upper catch; the former is actuated by the knives, but the upper catches of lifted hooks impinge against a fixed stop bar O′, P′: the catches and bar then prevent such hooks from moving forward. A second pair of knives, K′, L′, move out and in with K, L; at every inward movement they push back the tilted balks C against the stops O, P, for, unlike a negative dobby, there are no springs upon the healds to effect this movement. The

four knives travel in converging slots W, W′, and the three-armed lever M, Fig. 76, is placed near the inner end framing, hence the hooks are pushed, not drawn out.

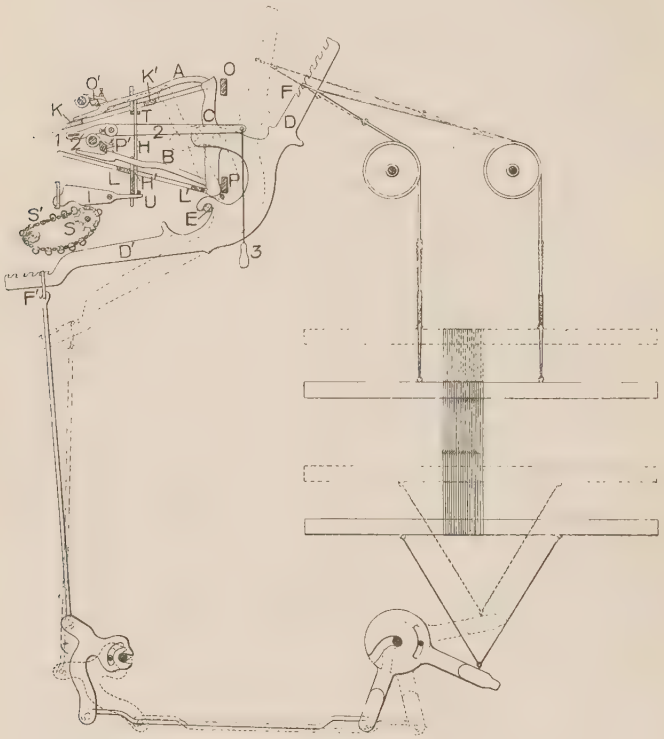


Fig. 75.

Hattersley's ordinary levelling motion forms part of this dobby, namely, a bar 1 is placed against the underside of all hooks in the upper row; it is fixed in one arm of a lever 2, and by drawing down a handle 3, attached to the

other arm, the hooks in the top row are lifted above the top knife, therefore no shaft will be disturbed when that knife next moves outward.

The knives K, K′, L, L′ are differentially driven. When

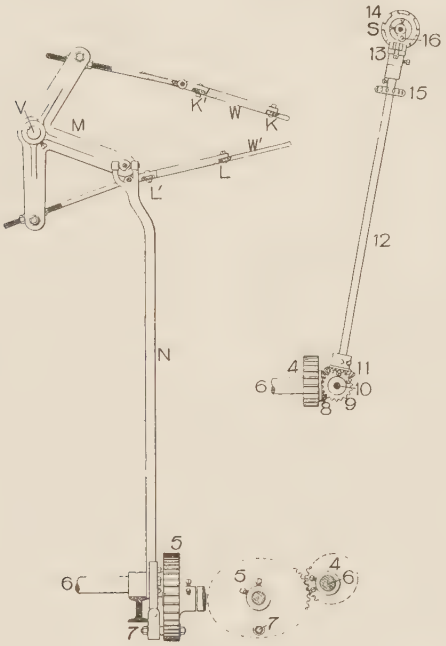


Fig. 76.

midway in their course they move the healds at a maximum speed, but as they approach either extremity the speed is reduced. This is accomplished by an eccentric wheel 4, and an elliptical wheel 5, Fig. 76. The wheel 4 is fixed upon the lower loom-shaft 6, and drives 5 round a stud. 5 also carries a crank pin 7, to which the lower end of a

rod N is attached; the upper end being connected to the three-armed lever M. The lag-barrel S is divided into two portions; one operates the shedding, the other the picking and shuttle boxes. It can be driven forward or backward, or be stopped, at pleasure, in the following manner:—A bevel wheel 8 is compounded with the eccentric wheel 4, and drives two loose bevels which are set to face each other on a shaft 10, and both gear with 8, at all times. Between these wheels a hoop, with a ring groove in the middle and a clutch face at each end, is loosely mounted upon a key in the shaft 10. By moving a lever one notch, the picking may be put out of action, in which event the lag-barrel S continues to turn normally. The hoop may also be engaged with either bevel; one will cause the wheel 11, on the shaft 12, to turn in the opposite direction to the other, and a similar motion will be conveyed to the lags. On the top of 12, a slide and peg 13 are fastened to drive intermittently a face star wheel 14, which is secured upon the shaft of S. By withdrawing a spring pin 16, each section of the lag-barrel may be turned by a hand adjusting wheel. The device for driving the lags is also used to drive the taking-up motion.

PART VI

JACQUARD SHEDDING

A JACQUARD machine is a piece of apparatus for selecting and lifting the warp threads for each shed. It is used for large patterns in which all or most of the threads in a repeat move independently, and by its aid elaborate details

and flowing lines may be readily reproduced in a texture. The harness that accompanies this machine has been used, with other selecting parts, for several centuries.

Joseph Marie Jacquard has received the credit for inventing the machine that bears his name, but his contribution towards the solution of the problem was small compared with the contributions of his predecessors. Between the years 1725–46 several Frenchmen developed and almost perfected this machine. Working models of their inventions are to be found in the Conservatoire des Arts, Paris, and in the Municipal College of Technology, Manchester. These afford conclusive proof that Jacquard invented little that is essential to the machine. Even the claim that by combining the scattered pieces of former inventions he produced a beautifully simple and compact machine cannot be maintained, for except in the prism Jacquard's machine was inferior to one invented by M. Falcon in 1728. In 1746 M. Vaucanson invented a machine which chiefly differed from the Jacquard in having an endless band of perforated paper passed round a perforated cylinder, and rotated automatically, instead of an endless chain of paper cards turning on a four-sided perforated prism. Both machines occupied similar positions on the loom, and both cylinder and prism received lateral and rotary movements. The cards and prism were invented by Falcon, but Jacquard perforated the prism on each face.

The parts of a Jacquard are cards, prism, needles, needle board, heel rack, hooks, and griffe, together with suitable framing and means for causing each part to do its appointed work. Of these Jacquard, 1801–4, used Falcon's cards, prism, needles, heel rack, hooks, griffe, and framing, but he drilled the needle board and prism to form diagonal instead of vertical rows of holes, and perforated

the cards to suit the arrangement of the needles. This plan was soon abandoned in favour of Falcon's. The Jacquard machine is essentially Falcon's invention inverted to give a direct, instead of an indirect action, and fixed in a similar position on the loom to Vaucanson's machine. Jacquard also added parts which enabled the prism to move out, make $\frac{1}{4}$ of a revolution, and move in again; but these movements closely resembled those for Vaucanson's cylinder. As left by Jacquard, the machine was without grid, the hooks were simply coiled at the bottom, and a short horizontal piece was left for each to rest upon; they were easily turned from the griffe, and when turned were useless.

This machine has been used for more than a century, and during that time most of its parts have been modified. Inventors have endeavoured to increase the speed, reduce the cost of working, and render all the parts reliable. As a result of these numerous efforts it is impossible, within the limits of the present treatise, to deal with all the modifications of the original model, but the most important will be considered. The various makes may be classified as single-acting, centre shed, double-acting single cylinder, double-acting double cylinder, open shed, twilling, and machines specially constructed to reduce the number or size of the cards required for a given pattern.

The size of pattern obtainable from a Jacquard depends upon the number of figuring needles available and the closeness of the warp threads. It is also customary to name a Jacquard according to the number of needles it contains, as a 100 or a 400 machine, those needles intended for selvages being omitted.

The usual sizes are—

100	in which the needles are arranged in	4	tiers and	26	to a row	=	104
200	,, ,,	4	,,	51	,,	=	204
200	,, ,,	8	,,	26	,,	=	208
300	,, ,,	6	,,	51	,,	=	306
300	,, ,,	8	,,	38	,,	=	304
300	,, ,,	12	,,	26	,,	=	312
400	,, ,,	8	,,	51	,,	=	408
500	,, ,,	10	,,	51	,,	=	510
600	,, ,,	12	,,	51	,,	=	612
800	,, ,,	8	,,	51	two sets	=	816
900	,, ,,	12	,,	77	single card	=	924
900	,, ,,	12	,,	51 + 26		=	924
1200	,, ,,	12	,,	51	two sets	=	1224

For higher numbers, and also for some of those given above, it is a common practice to place two or more machines of smaller capacity over one loom.

Cards are pieces of millboard which are cut into a suitable size for covering the needle space of the machine they are intended to be used with. A 400 card for a machine of the usual gauge is $16\frac{3}{8}''$ long by $2\frac{7}{16}''$ wide, and a 600 card is $16\frac{3}{8}''$ long by $3\frac{7}{16}''$ wide. The weight of uncut cards varies considerably; if used with a 400 hand-loom machine one hundred may not weigh more than $3\frac{1}{2}$ lbs., whereas cards of the same size for power-looms may exceed 7 lbs. per hundred.

Single-Lift Jacquards

When perforated, laced, and wired, as described on pp. 278 to 302, cards are suspended by the wires from a cradle, and passed over a four-sided wooden prism called a cylinder, see A, Fig. 77. Each face of A is perforated to correspond with the number and disposition of the needles in the machine. Every hole is drilled as large as the rigidity of the cylinder will admit of; this is done to leave

a needle free to enter a hole without risk of touching

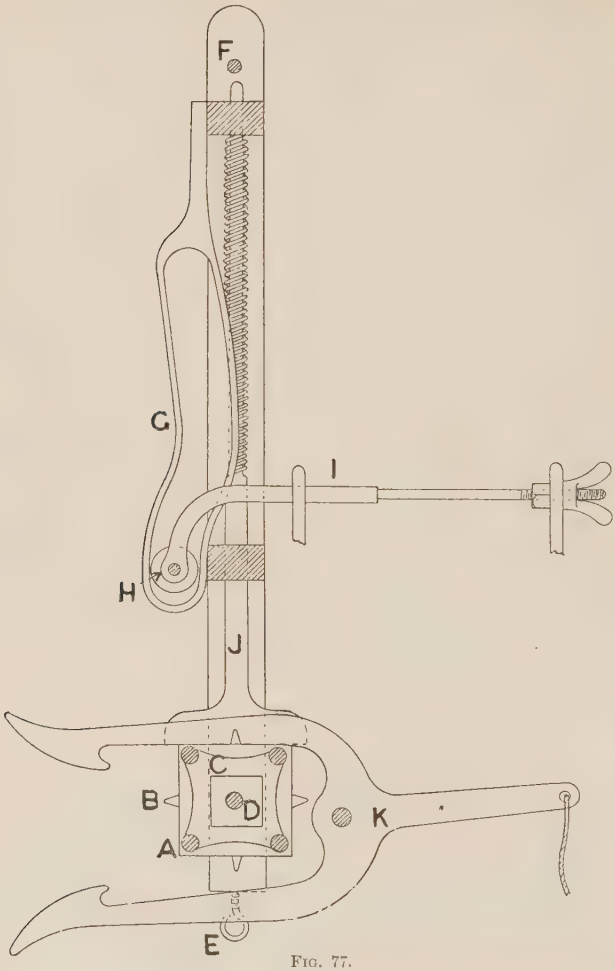


FIG. 77.

the wood. Two tapering wooden pegs B are driven into

every face, and protrude about $\frac{1}{2}''$; or two similarly shaped brass pegs may be supported upon spiral springs and secured by sinking an adjustable brass plate into the surface of the cylinder. The pegs are outside the first and last rows of holes and midway between the cylinder edges; they draw forward and hold each card in turn, with its holes over those in the cylinder; but two flat springs on the outer and two wire springs on the inner faces of the cylinder assist the pegs to hold the cards in position.

A metal lantern C is fastened on each end of A; its rounded edges coincide with the cylinder edges, but between these the metal is removed to a depth of about $\frac{1}{2}''$. Beyond each lantern are two gudgeons, D, which support the cylinder; their bearings are in a frame that either swings upon centre pins or moves horizontally. Those who favour a swinging cylinder claim that little power is required to move it; that the parts are not liable to wear through neglecting to oil them, and that a minimum of oil is required. On the other hand, the cards are liable to be thrown off the pegs, and the cylinder holes are carried above or below the needle centres instead of remaining facing those centres; the framing must also be taller than that required for a sliding cylinder.

Some cylinders are moved from the griffe, others move independently of the griffe. The former method is usual for single-lift machines, but there is a tendency to push descending hooks off, and to wear notches in, the lifting blades, as well as for the needles to puncture the cards. This defect is fully explained in Dobby Shedding, p. 87.

Independent cylinder motions are general for double-lift machines, and are to be preferred, because they can be timed to suit the movements of the griffe. Fig. 77 shows

a common method of working a swinging cylinder from the griffe. The cylinder A is supported in bearings which rest upon screws E, for the purpose of vertical adjustment. In hand-loom machines the batten consists of two upright and two cross pieces of wood. In power-looms metal is used. The batten swings upon two centre pins at F, which are screwed into brackets projecting from the machine framing; the screws are pointed to enter conical holes in the batten, and they also provide for lateral adjustment.

A metal swan neck, G, is screwed to the upper and lower rails of the batten. It has a curved groove for the reception of a bowl H, and H is supported by a pin between the prongs of a forked rod I. This rod has a thread cut upon its rear end and is fastened to the griffe block by lock and wing nuts; near the batten it is square in section and passes through a similarly shaped hole in the griffe to prevent the bowl H from twisting. As the griffe moves I and H up and down, the curved slot in G causes the cylinder A to be alternately pushed away from and drawn against the needles. The period during which A is held stationary against the needles is regulated by the length of the vertical portion of the slot at the base of the swan neck G. See also Fig. 82.

When pressed against the needles a cylinder face must be parallel with the needle plate and be free from any tendency to rotate. In order to provide for these requirements two hammers, J, are fixed in the batten with the head of each resting upon the upper surface of a lantern C. The shank of each hammer is square in section near the head, but is cylindrical for the greater part of its length. The cylindrical portion passes through a round hole in the upper, and the square portion through a square hole in the lower, rail of the batten. An open-coiled spring is

loosely mounted upon each hammer shank to abut upon the square part and the upper rail, thus leaving the hammers free to move up and down without twisting. In case a cylinder A is removed, the hammers J are prevented from falling out of the batten by turning two thin pieces of wood or iron, secured upon the lower cross rail, into grooves cut in the square portions of the hammers' shanks.

A forked catch K, with a hook on the inside of each prong, swings freely upon a pin in the machine framing. Normally the upper prong rests, by gravitation, upon the top of one lantern, and the lower prong is quite clear, even when the cylinder edges are vertical. This catch is set to permit the cylinder to move out a short distance without obstruction, but ultimately the outer edge of the lantern is engaged by the catch, when further lateral movement of that edge is stopped and a rotary one set up to the extent of $\frac{1}{4}$ of a revolution. As the cylinder turns, each hammer head is lifted, and the contracted springs assist in steadying the movement.

A weighted string is tied to the straight end of K, and if the top catch is acting, the weight is suspended from a fixed hook, but if the cylinder is required to turn in the opposite direction, the weight is released; it then pulls the bottom catch against the underside of the lantern, and lifts the top one out of the way.

A sliding cylinder A, Fig. 78, is supported in two bars L, that move in four brackets, bolted in pairs to the outside framing. Upon each bar a swan neck G is fastened, and the pins on which two bowls H turn project from the ends of the griffe. Therefore, as H, H move up and down vertically, the bars L receive a lateral reciprocating motion. Sliding bars have been indirectly connected to two levers by spiral springs, so that, in case a cylinder is presented

to the needles cornerwise, the springs will expand and thus prevent serious injury.

Similar lanterns, hammers, catches, bearings, and adjusting screws to those already described are found in both types of machines.

A machine invented by Frederick Goos in 1842 has its

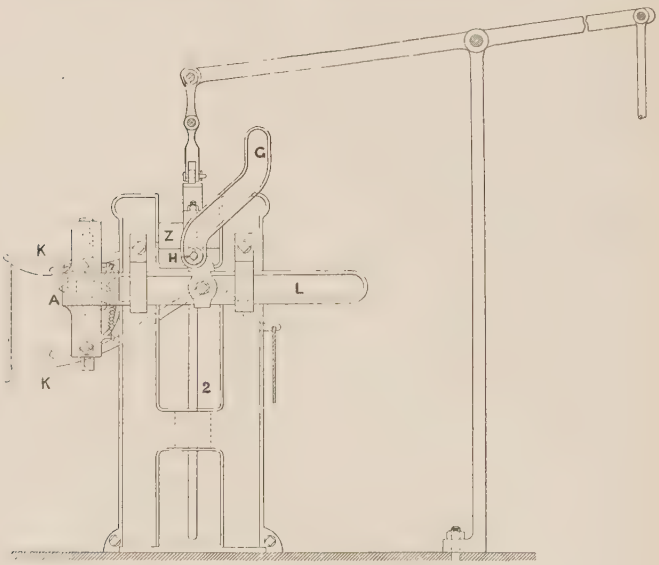


FIG. 78.

cylinder A, Fig. 79, turned in the usual manner by catches, but it slides upon adjusting plates placed inside a pair of slotted arms. The griffe Z works in two slots in the end framing, and has a rack at each extremity with teeth that extend beyond the framing, and engage with a series of studs on the inside of two wheels 5. The studs are arranged in semicircular form, so that as the griffe Z moves

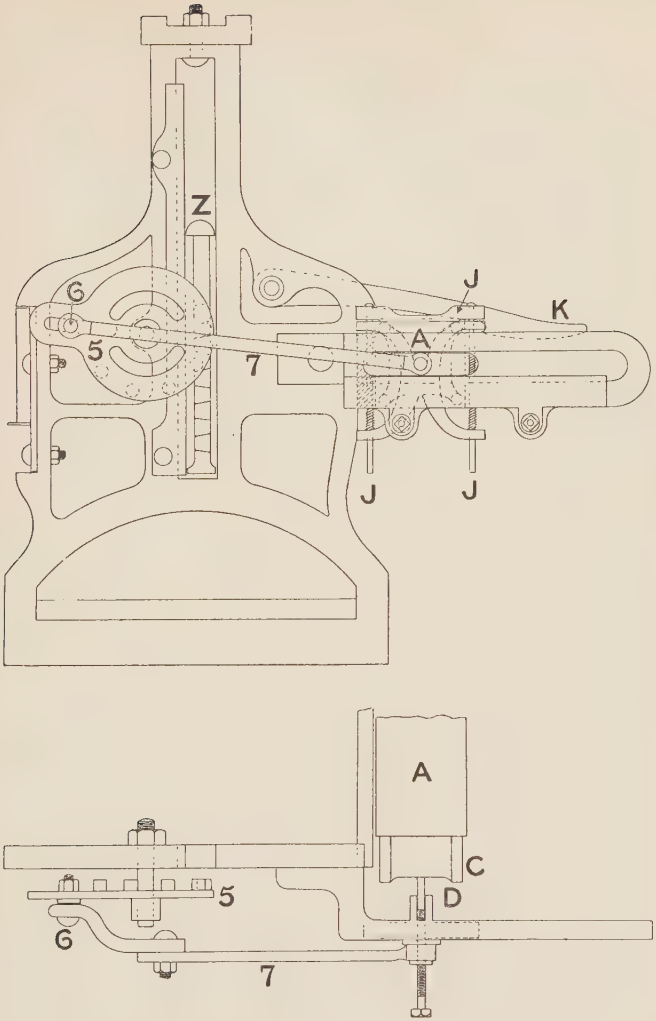


Fig. 79.

up and down, the wheels 5 will turn approximately halfway round and force out and draw in the cylinder. Two arms 7 unite the cylinder A with the wheels 5 by studs 6. These arms are made in two pieces to facilitate adjustment, and the studs 6 pass the back centres of the wheels 5 to give a pause to the cylinder each time the needles are pressed back.

Each hammer J is pulled against the cylinder A by two springs which are loosely threaded upon a pair of shanks that point downward.

Instead of rotating a cylinder by a single or a double catch, various methods have been devised for rotating it positively. For example, Messrs. Schaum and Uhlinger, of Philadelphia, U.S.A., have discarded the four-sided prism, and in its stead they mount two large pulleys upon a shaft, and insert twelve conical pegs into the periphery of each, at equal distances apart. The shaft and the pegged pulleys are positively, but intermittently, driven by a twelve-sided star wheel which is mounted upon the rear end of the pulley shaft. Two chains and four chain wheels are employed to drive the star wheel. One chain is driven from the crank shaft of the loom and communicates motion to a pair of chain wheels ; these are compounded by means of a clutch, so that by opening the latter the cards may be turned forward or backward by a winch handle. The second chain is driven by one of the compounded wheels, and conveys motion to a shaft fitted parallel with, but beneath, the pegged pulleys. This shaft is provided with a collar and crank pin ; as the former rotates, it rolls against the curves of a star wheel, while the latter enters a notch and drives the star. At each movement of the star wheel a fresh card is placed in front of the needles. The pegged pulleys and cards receive a slight

lateral movement from a pair of swan necks attached to the griffe; and inside the pulleys a perforated board advances with the pulleys and presses each card into contact with the needles.

With a four-sided star wheel, an ordinary cylinder could be similarly driven.

Another plan is illustrated in Fig. 80, where a connecting rod A is vibrated by an eccentric on the main shaft of

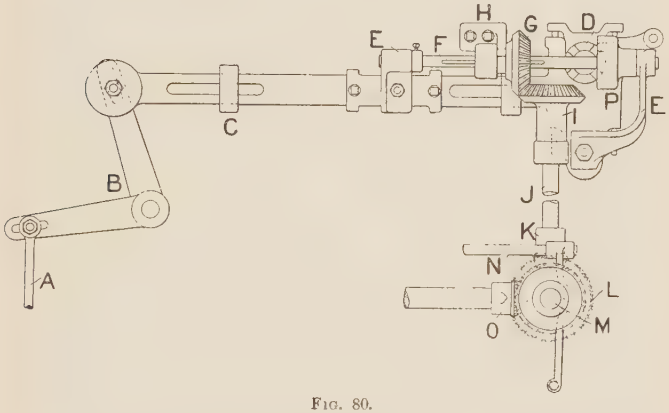


FIG. 80.

the loom. By means of a cranked lever B, the rod A gives a horizontal reciprocating movement to two rods C, which support the cylinder D. One of these rods has two bearings E, E for a shaft F, hence they partake of the sliding movement. A key is fitted in F, and a bevel wheel G is loosely mounted upon it. A ring groove in the boss of G receives the lower end of a bracket H which is rigidly bolted to the machine framing for the purpose of preventing the wheel from sliding with the shaft. Upon one cylinder gudgeon a four-notched face star wheel is fixed, and upon F a crank pin is mounted in a collar P. The periphery of the

collar bears against the curves of the star wheel to steady it, and the pin enters the notches to drive it.

A vertical shaft J carries two bevel wheels; the upper one, I, gears with G, and the lower one, K, gears with a bevel L on a horizontal shaft M. The last-named shaft can be driven from any convenient part of the loom, but it is usually furnished with two bevels, both of which are capable of sliding upon a key in M. The teeth of one are set to face those of the other, and a similar wheel O drives them, but can only engage one at any time. By moving a lever N one wheel will slide into, and the other out of, gear with O, and thus reverse the direction of movement in the wheels, shafts, and cylinder.

FIG. 81.

Cards operate hooks through the medium of needles M, Fig. 81. They are made from round wire; one end being straight, the other bent to form a loop approximately $\frac{3}{8}''$ long. An eye is made by coiling the wire to form an opening large enough for a hook to pass through. The distance from point to eye depends upon the position of the hook that a needle is to govern. In a 400 machine there are eight rows of hooks, and all the needles of one row have eyes and points equidistant, but since the hooks are placed row behind row, the needle eyes must be formed in eight different places to bring each facing its hook. Needles are arranged in horizontal rows; the number of rows and the number in each row vary with the capacity of the machine, but 612 needles usually occupy a space of 13·75″ by 3·025″, although machines are built with 1078 needles, forming

14 rows of 77 that only occupy a space of 13·64″ by 2·48″.

The straight end of each needle is passed from $\frac{1}{4}$″ to $\frac{3}{8}$″ through a needle board N, Fig. 82, or an iron plate, drilled to the gauge of the cylinder, viz. 0·275″, but with holes just large enough to allow the needles to move to and fro, also with two large holes to receive the cylinder pegs. The looped ends of M are supported by a heel rack O, consisting of a scalloped framing capable of holding stout wires in parallel tiers. The loops pass on their flats between the wires, and a pin P is threaded through all in one vertical row of needles. The pins and loops limit the lateral movement of all the needles and prevent them from being withdrawn from the needle board or the heel rack.

Holes are drilled through a detachable spring box Q, to correspond with the positions of the needles, each being large enough to receive a brass spiral spring S, from $1\frac{1}{4}$″ to $1\frac{5}{8}$″ long, by $\frac{3}{16}$″ in diameter. Vertical pins R are passed through holes in the rear of the box Q, and athwart the lines of springs; each holds one row of springs in position, and permits of their removal in case repairs are necessary. The forward end of a spring abuts against the rear end of a needle loop, and pushes it upon a pin P; by so doing, the needle point is thrust in advance of the board N, but can be forced back by exerting sufficient pressure to contract a spring S. This occurs every time a blank in a card is carried by the cylinder A to within $\frac{1}{8}$″ of the needle plate N.

The hooks T are bent at both extremities; the upper bend forms a catch, and the lower one a loop about $1\frac{1}{2}$″ long. Each hook is held in a vertical position by passing it through the eye of a needle and allowing the loop to rest

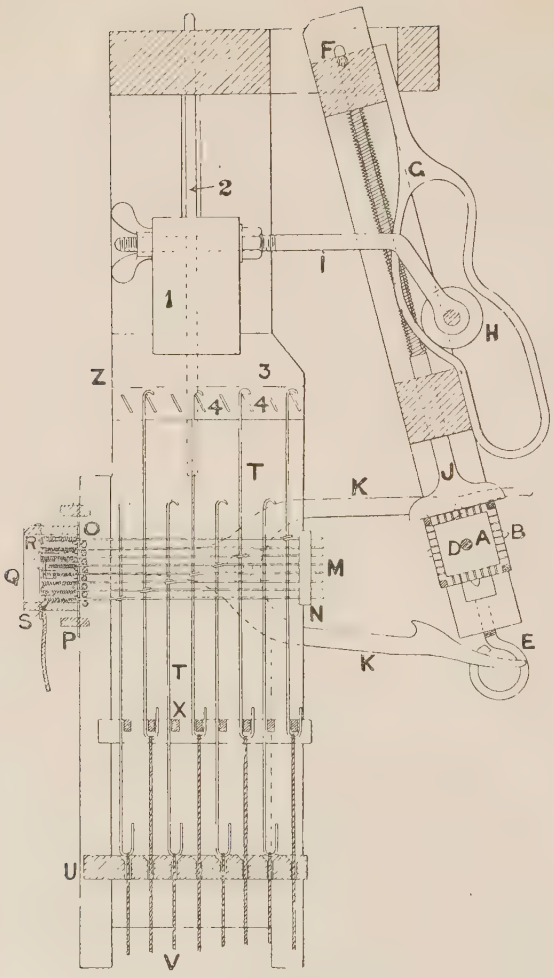


FIG. 82.

upon a bottom board U. This board is perforated in parallel rows at a distance of 0·275″ from hole to hole. But for machines with hooks $10\frac{1}{2}$″ long the distance from row to row varies from $1\frac{3}{16}$″ between rows 1 and 2 to 1″ between rows 7 and 8. The difference is intended to prevent the descending griffe knives from injuring the stationary hooks, for all needles are pushed back uniformly, but the bottom row being farther from the heads of the hooks than the top row, will cause their hooks to move through a greater space than those in the top row. In machines with long hooks the spaces are all equal, and from $\frac{7}{8}$″ to 1″ apart, because the difference in movement usually diminishes in proportion to the increased length of the hook.

The upper face of a bottom board U has a separate recess for the base of each hook T to sink into; by this means the board helps to hold the hooks with their heads facing the griffe blades.

A neck cord V is usually fastened on the loop of every hook by a "double hitch," see G, Fig. 118, for by this plan the hooks will not cut the cords to the same extent as if knots were used. An endless cord is also made by warping thin twine to the required length and thickness, and after tying the first and last strands and twisting all together, the neck cord is dropped over a hook, as in H, Fig. 118. Hooked wires have also been used instead of neck cords, but they lack flexibility. A neck cord terminates about 8″ below the bottom board. If the heads of the hooks were allowed to turn, the griffe could not lift them, so turning is prevented by a grid X, consisting of two end pieces of wood or iron, into which strips of wood, or stout wires, are fitted at right angles. A bar of this grid rests loosely in the loops of each line of hooks T,

and when the machine is in motion the grid rises and falls with the hooks. For satisfactory work, the bottom bend of a hook should be, say, $4\frac{1}{2}''$ instead of $1\frac{1}{2}''$ long, for then a lifted grid would remain inside the loops of all hooks left down.

Brackets bolted to the top of the Jacquard, or supports rising from a platform, carry a fulcrum pin for a lever which is connected by a rod to a crank, or cam, fitted on some convenient part of the loom; a link also unites the lever with the griffe Z. In these machines the griffe gives motion to the cylinder A, and to the hooks T. All parts of a griffe are attached to a block 1, that either moves vertically in the slotted end framing, or else a pair of spindles 2 rise and fall in double bearings fixed about 6″ apart. In machines with 26 hooks to a row, two thin wrought-iron plates 3 are bolted to the griffe block, but in those with 51 or more hooks to a row, a third plate is placed midway between the outer ones. Each plate has a narrow, diagonal slit, about 1″ in depth, punched through it for every row of hooks. Bars, or knives of strong hoop iron, 4, with feather edges, are threaded through the slits and retained by passing a wire through holes previously drilled in the knives and outside the plates 3; after which the wire is bent at each end to make it secure. Every knife edge is fitted close to a row of hooks, but is not allowed to press against them. A knife and a hook form an angle large enough to permit the lower edges of the former to pass the heads of the latter. If the knives were upright, they would descend upon the unlifted hooks and bend them.

The action of a Jacquard is as follows:—Cards are passed over the cylinder A and pressed against the needles M; the needles enter the perforations and remain stationary,

but blank places push back the needles and tilt the heads of the hooks T, for each neck cord V serves as a fulcrum for a hook to move on. At this time the upper edges of the knives 4 are from $\frac{3}{16}''$ to $\frac{1}{4}''$ below the heads of the hooks, and as Z begins its upward movement, the blades lift vertical hooks, but miss inclined hooks.

A mounting thread is tied to a coupling and to a neck cord V, hence a rising hook will lift the coupling and the warp it controls to the top line of a shed.

The cylinder A begins its outward journey when the griffe is from $\frac{5}{16}''$ to $\frac{3}{8}''$ above the level of the hooks to be left down, the springs S immediately force the free needles M into their normal positions, the catches K turn the cylinder $\frac{1}{4}$ of a revolution, and the next card is in position for repeating the operations. Single-lift machines are still used in the manufacture of silk, cotton, linen, and woollen fabrics when, for other than shedding reasons, high speeds are unattainable.

Since Jacquard introduced his machine, mechanicians have not only modified and improved its details, but have aimed at setting aside most of the features considered essential to it.

The great cost of cards has led to endeavours to discard them, or to reduce their numbers and dimensions. Celluloid, and endless bands of perforated paper, approaching the thickness of ordinary writing-paper, have been used. Wire gauze, and canvas made from various textile fibres, have had some of their meshes closed with varnish to form a pattern, and have been used as card substitutes. Endless bands of flexible metal have also been painted with an insulating varnish, rotated automatically, and acted upon by electro-magnets placed in front of a Jacquard, but without important results.

Neck cords have been carried entirely through the machine and used instead of hooks. Hooks have been made to hold a needle point forward without spring or other contrivance; but at present these and other similar changes have a limited application.

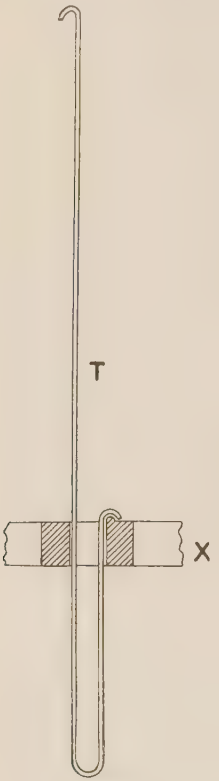


FIG. 83.

A beneficial change in the hook is shown in Fig. 83, where the bottom loop is turned up about 6″ and curved sharply outward to form a second catch. A cast-iron grid plate X has semicircular ribs, approximately $\frac{1}{4}$″ in diameter, running in parallel lines lengthwise of the machine; X supports the bottom bends of the hooks T, and a separate slot for each hook effectually prevents turning, for the hooks are never lifted out of the grid. When single-lift machines are fitted with these hooks, the bottom board is retained, but it merely serves as a guide to the neck cords, for the hooks do not touch it by from $\frac{1}{2}$″ to $\frac{3}{4}$″.

With a coiled needle eye it is difficult to remove a damaged hook. On this account a modern needle has a cranked eye, as in Fig. 84. Extensive application has proved this needle to be efficient, and it leaves the hooks accessible for repairs.

Clinton G. Gilroy, in his *Art of Weaving*, says it is not perhaps generally known that M. Jacquard did not employ

perpendicular wires (as at T, Fig, 82) in the first machines which he constructed, but knot cords and trap boards. In John Murphy's *Art of Weaving* we are told that shortly after the introduction of Cross's counterpoise harness (about 1816) the French draw loom was imported from France, and the machine he describes is a cord machine. The inventor of the cord machine may, therefore, be Jacquard, but it has been attributed to William Jennings, of Bethnal Green, and the date given as about 1830. In it a neck cord V, Fig. 85, is passed vertically through the bottom board U, and the eye of a needle M through a perforated trap board Z, that takes the place of a griffe, and through a board W, at the machine head from which

FIG. 84.

all the harness cords are suspended. Above the head board a loop is formed upon each neck cord at X, for a piece of twine to be passed through the loops in one line, and so prevent the cords from lifting. Each neck cord is knotted immediately above the trap board when the latter is in its lowest position. The holes in this board are large enough to allow a knot to pass, but a saw slit runs into every hole and is only wide enough to take a neck cord;—see the detached portion of a plan view of Z—hence if any of the needles are pushed back their neck cords are pressed into counter-sunk slits which retain them, and when the trap board begins to rise, all cords in the slits are carried up with it. But since straight cords have their knots over the holes they will be left down. A batting board Q pushes the needles forward immediately the trap board reaches the bottom. In addition to the bottom board, another and

similar one is placed somewhat more than the depth of a shed below the first, and between them each neck cord has a leaden weight secured upon it to keep it in tension.

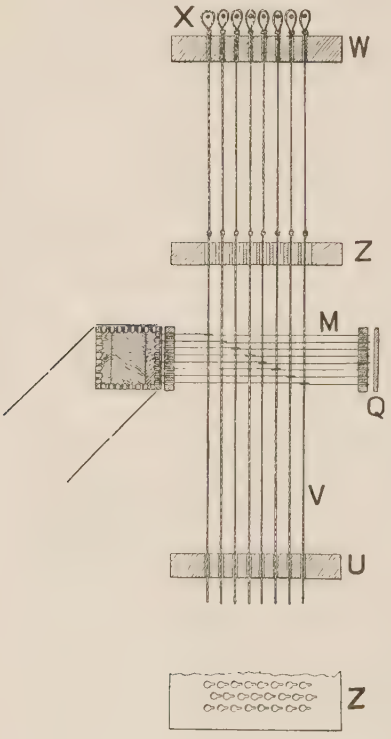


FIG. 85.

Occasionally the head and the trap boards reciprocate laterally, for the purpose of moving the cords out of the saw slits with greater certainty.

In 1842 F. Goos introduced a form of hook which dispensed with the spring box and springs. As now made, for machines with from 200 to 400 needles, the hooks T, Fig. 86, are $10\frac{3}{4}''$ long, and the straight leg is only $1\frac{1}{2}''$ shorter than the hooked one. Both legs are $\frac{5}{16}''$ apart at the bottom, but the top of the short one touches the long one. A stationary grid of stout wire 8 is bolted to the end framing $4\frac{1}{4}''$ below the hook heads, and each wire passes between the loops of one row of hooks; therefore, when any of the needles are pushed back, the legs of T are separated, and the springy nature of the

wire forces the needles forward as soon as they are liberated by the cylinder. To prevent the hooks from turning, a grid X is carried up and down by the griffe. This plan works well, but the parts are difficult to repair.

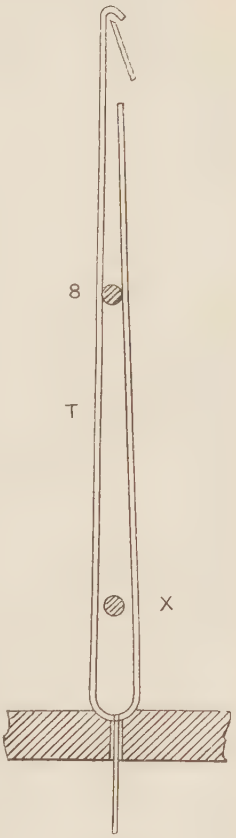


Fig. 86.

Centre Shed Jacquards

Owing to the necessity for closing one shed before opening another, single-acting Jacquards can seldom be run at more than 80 picks per minute; and the want of a counterpoised harness puts great strain upon the loom.

The Ainley Jacquard was invented in 1876 with a view of remedying both these defects, but in opening each shed it imparts a movement to every thread of warp, and sets up an objectionable swinging in the harness, especially when more than 150 to 160 picks per minute are attempted with a 45″ or a wider harness. The lifting crank of a loom has also to sustain the entire weight of the harness.

In construction the parts are simple and as readily repaired as those in other machines of equal capacity. Fig. 87 shows all that is essential to the machine: 4 is one blade of the griffe Z, the frame of which is united by a strap to a quadrant on the lever Y. A rod 12 also couples

Y to a lever 13, and a similar rod 14 connects the grid X with 13. An ordinary lifting apparatus is used to set the

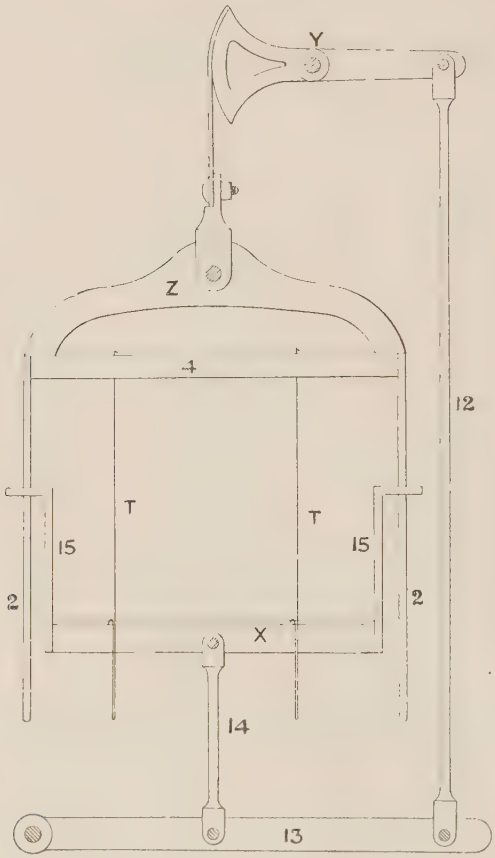


FIG. 87.

parts in motion; but as 4 ascends with all vertical hooks T to form a top shed, the grid X descends simultaneously

with all inclined hooks, therefore a shed is opened in about half the time required to form one by a single-lift machine. When motion is reversed, the blade 4 and grid X move towards each other. Both are steadied by fixing a pair of spindles 2 upon the griffe frame, and passing them through bearings formed in the brackets 15, which are bolted upon X. When the number of rising and falling hooks is unequal, a weighted lever may be lifted with a light shed, and in falling it will help to lift a heavy one to the centre.

In the United States of America and on the Continent of Europe, centre shed Jacquards are in extensive use. But it is unusual to actuate the griffe from above, as in Fig. 87, owing probably to the practice of placing looms in storied buildings where head room is limited. By lifting the griffe from below a Jacquard becomes more compact, and the plan might with advantage be more generally adopted in this and other styles of machines.

Double-Lift Single-Cylinder Jacquards

Double-lift Jacquards possess an advantage over single lifts, in so far as the saving of power is concerned, for the weight of a falling shed helps to lift a rising one, and, since they move the warp through a reduced space, less strain is put upon the threads. But their chief advantage consists in giving increased speed without increased wear and tear; for most, if not all, the moving parts work at half the speed of the loom shaft. Where the fabrics are thin, and the weight to be lifted is irregular, double-acting machines at times cause cracks to show in the figure; this may be due to the warp threads passing each other about the same time the slay is beating up the weft.

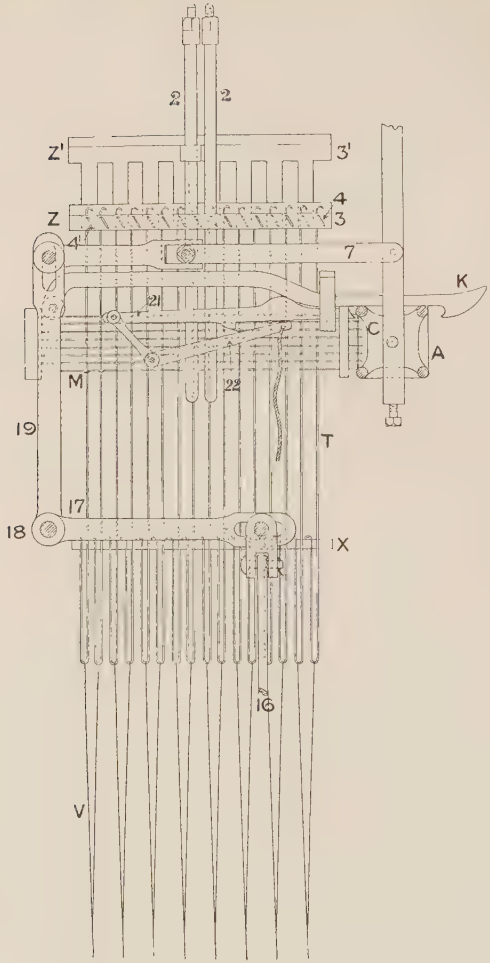


FIG. 88.

In 1854 John and William Crossley introduced a machine which embodied the principle of governing two hooks from one needle; thus a 408-needle Jacquard had 816 hooks arranged in 16 rows of 51 hooks each. Originally alternating rows of long and short hooks were used, and the neck cords from one long and one short hook were united. The cylinder was drawn in by the descending griffes, and pushed out by an open-wound spiral spring. The needles, also, had coiled eyes. But this plan was discarded in favour of that illustrated in Fig. 88, in which a pillar rises from a platform to provide a bearing for the fulcrum pin of two lifting levers (see J, K, Fig. 111). The inner end of each lever is connected to a griffe Z, or Z′, by links and studs. Two rods connect the outer ends of these levers to a double-throw crank on the bottom shaft of the loom. Or, two racks may be bolted upon the cross heads of the griffes Z, Z′, so that their teeth shall face each other. A spur wheel is then keyed upon a cross shaft to connect amd drive both racks in opposite directions. An arm at one end of the shaft receives motion from a lifting rod operated by a single-throw crank from the main shaft of the loom. Upon each end of the griffe frame Z a wrought-iron plate 3, Fig. 88, is bolted and slotted to receive eight griffe blades 4; a plate is $\frac{1}{16}''$ thick by $2\frac{3}{4}''$ deep, and the blades are $1\frac{3}{8}''$ deep. Two similar plates 3′ are bolted inside the end frame of the griffe Z′, but they are 8″ deep, and contain seven vertical slots, each $6\frac{1}{2}''$ deep. A slot is wide enough to allow a knife of Z to move up and down inside it. The plates 3′ support a similar series of blades 4′ in slits near the bottom of the teeth. The frames Z, Z′ are steadied by keying a pair of spindles 2 upon them, and causing the spindles to move freely in bearings formed on the machine framing.

The hooks T are 16″ long by $\frac{5}{16}$″ across the bottom bend; they are supported by a grid X, and sink $4\frac{1}{2}$″ below it. All the rows are about $\frac{5}{16}$″ apart, and hooks from contiguous rows are coupled by tying two neck cords V together at about 9″ below the grid. The needles M are $16\frac{1}{2}$″ long, and have double-cranked eyes formed as shown in Fig. 89; those in the top row actuate the hooks in rows 1, 2, and successive rows of needles govern following double rows of hooks.

The motion of the cylinder A is independent of the griffes Z, Z′; it is derived from a crank on the main driving shaft, and is conveyed by a rod 16, to an arm 17, which is keyed upon a horizontal shaft 18, and 17 should be long

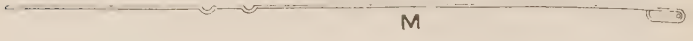


FIG. 89.

enough to leave 16 vertical when the driving crank is on the top or bottom centre. Two arms 19 are also fastened upon 18 to actuate two bars 7, attached to the batten of a swinging cylinder.

As the crank revolves it vibrates the rod 16, the levers and shaft 17, 18, 19, the bars 7, and the cylinder A. Each part being adjustable, it follows that A can be set to strike the needles M when either griffe Z or Z′ is too low to allow the hooks T to be pushed off, also that the duration of the pause can be varied. If the pause is too short, some hooks will be lifted that should be left down; if too long, the cylinder will move rapidly, throw the cards off the pegs, and the needles will puncture them. When the griffe cranks are on their top and bottom centres, the cylinder crank should be on or near its front centre.

A single catch K, Fig. 88, turns the cylinder A forward, but a bar 21 is used to turn it back manually; this bar slides in a bearing bolted to the framework and is on a level with the top corner of the lantern C; a catch on the underside limits its forward movement, and a curve on the top edge lifts the catch K off the lantern C before a backward motion is given to A. A cranked lever 22 moves freely upon a pin, and one arm supports the rear end of the bar 21; the other arm has a cord tied upon it for the weaver to pull. Every time the cord is pulled, the bar 21 slides out and turns the cylinder A one-fourth of a revolution in the backward direction.

The griffes Z, Z′ rise and fall alternately, and a card is pressed against the needles when both griffes are at opposite extremities of their movement. A hole in a card will leave two hooks vertical, and the next griffe to rise will lift one of them If, on the succeeding card, a blank is opposite the same needle, before that needle can push back the lowest hook it must act through the lifted one; this puts a certain amount of strain upon both hooks and needles, but it can be reduced by allowing a lifted hook to swing slightly in the grid X, the knife serving as a fulcrum.

By tying two neck cords together, both hooks act upon the same warp thread. If one hook lifts a thread to the top shed, immediately that hook begins to fall the thread falls with it; for although the second hook begins to rise as the first begins to fall, the lifted hook left the second neck cord slack, as at V, Fig. 90, and until it tightens the rising hook can have no effect on the warp. At the centre of a shed the ascending and descending hooks meet, and the former again takes the thread to the top. But where the warp threads are to change positions, one arrives at the bottom as the other arrives at the top (see Fig. 12).

When in action this machine has a tendency to twitch the warp and break the neck cords as the direction of motion is reversed; the rapid strokes of the cylinder upon the needles also injure the cards, and prevent the machine from moving as rapidly as one with two cylinders. Still, its speed greatly exceeds that of a single lift. Its central features may be summarised as follows: It lifts a warp thread any number of times in succession without allowing it to sink to the bottom. It forms a shed in a shorter time, and puts less strain upon the threads than a single lift, hence weaker yarns can be used; but weft is beaten home in a semi-open shed. Since the cards form one set, there is no fear of their proper sequence being destroyed. Its defects are: That the cards are liable to be thrown off the cylinder, to be broken, and punctured by the needles. The hooks and needles are subjected to considerable strain, the neck cords break, and double necks are more difficult to tie up level than single ones.

Two flat steel springs, fastened by set-screws to the upper cross rail of the batten, press a card against the outside face of the cylinder, and two pieces of steel wire, similarly attached to the batten, press a card upon the inner face of the cylinder; hence the springs hold the cards on three faces, and to a large extent prevent them from leaving the pegs.

High speeds often set up excessive vibration amongst the hooks and cause a falling griffe to descend upon the hooks left down and bend them. This has led makers to lengthen the hooks above the needles, and deepen the griffe blades, so that in their lifted positions the bottom edge of a blade will be always below the heads of the unlifted hooks. Or the same result may be achieved by extending a hook leg above the top bend, and thus prevent

the lifted griffe blades from reaching the top of a stationary hook.

Notwithstanding these and similar changes, the majority of Jacquards now in use are furnished with blades and hooks as previously described.

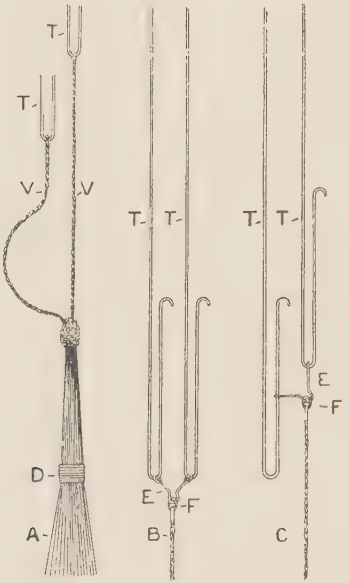


FIG. 90.

Many devices have been placed upon the market which aim at removing the objectionable double neck cords V. One consists in the substitution of a double hook for two single ones, as in Figs. 96, 105; others in connecting the lower portions of two hooks by a clip which rises and falls with a moving hook and slides up and down a stationary one. For a device of the latter type J. Hillas, in 1889,

achieved the greatest measure of success. His invention is illustrated at B, C, Fig. 90, together with the plan A he desired to supplant. The drawing A shows the lower portions of two hooks T with their accompanying neck cords V; one hook is lifted, the other left down, and one cord is tight, the other slack. To these neck cords a group of mounting threads D are attached. In the drawings B, C a wire link E unites two hooks T and carries a ring F, from which a single neck cord is suspended. At B both hooks are down and the link rests on the base of the loop of each, but at C one end of the link is suspended from the loop of a lifted hook, while the other end has ascended the short leg of the unlifted hook. When the opposite hook lifts, the position of the link will be reversed. At the change of direction, the effect upon the warp is easy, but the links and hooks wear each other.

The device on Crossley's machine for turning cards back only partially fulfils the requirements, for it is frequently necessary to turn cards forward as well as back; the former can only be done by ascending to the level of the Jacquard and turning the cylinder by hand. A better plan is shown in Fig. 91, where a four-sided star wheel A is fixed upon one of the cylinder gudgeons B, and adjacent to it a lever C is loosely mounted upon B. This lever is provided with a stud at D to serve as a fulcrum for a bent lever E, and a stud F, in E, is capable of engaging the star wheel and turning the cylinder in either direction. A spiral spring G unites one arm of E with C, and opposite ends of a cord H, I are attached to C and E respectively. The cord must be long enough to place the loop in a convenient position for the weaver to operate. Two projections J, on C, limit the swing of E, as well as cause C and E to swing together.

If the cord H is tight and I is pulled, as in the left-hand portion of the figure, the stud F, being above the centre of A, will turn the cylinder backward. But if I is tight and H is pulled, as in the right-hand portion of the figure, F being below the centre of A, the cylinder will turn forward.

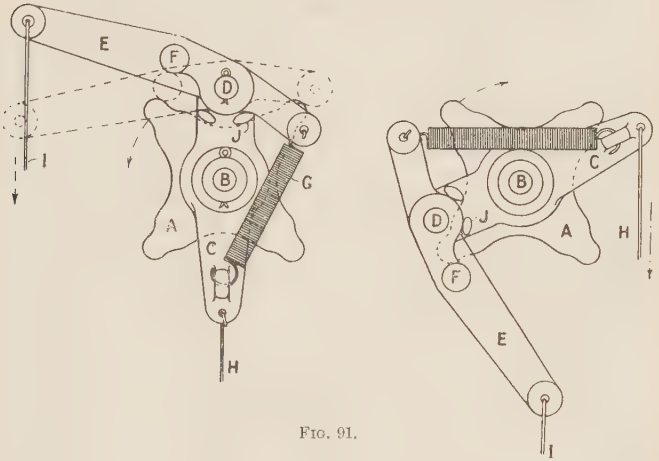


FIG. 91.

DOUBLE-CYLINDER JACQUARDS

Double-lift double-cylinder Jacquards are theoretically the most perfect, for everything moves at half the speed of a slay, and wear and friction are reduced to a minimum. But a set of cards is divided into two parts—one providing for odd picks, the other for even ones, and this gives considerable trouble to the weaver. As the cylinders strike alternately, they should present the cards to the needles in consecutive order; in practice, however, it is difficult to apply anything that will prevent the cards from getting out of their true sequence. High speeds have rendered this a serious matter, for a considerable length of material is woven in a short time, and if the cards are not working

properly, either the damaged fabric must be unwoven or the piece will be spoiled.

In Fig. 92 this machine is seen to consist of two single-lift Jacquards combined in one frame. All the hooks T face the cylinder from which they are governed, but the bottom loops of one set are bent forward, while those of the other set are bent back; this is done to distribute them equally along the surface of the grid X. Two neck cords V from contiguous rows are tied together, therefore the hooks forming pairs are actuated by the needles M, through cards on different cylinders. If one needle is at the top of one set, the other is at the bottom of the other set; for this reason half the cards must be laced so that their progressive numbers will read from left to right, while those of the other half will read from right to left.

Both cylinders A, A′ are coupled by bars, so that when one touches the needles the other is as far from them as possible; they are moved independently of the griffes Z, Z′, by similar mechanism to that described for the Crossley machine, but the eccentric for driving these cylinders works at half the speed of the former, hence it must be driven from the bottom loom-shaft, as at O, Fig. 111, or by gearing from the top shaft. Assuming the cylinder A to be pressing card 1 against one set of needles, cylinder A′ will be holding card 2 facing the other needles; then as A moves out, the griffe Z ascends, A′ moves in, and griffe Z′ descends.

Numerous parts have been applied to prevent the cards from being presented out of sequence, but defective construction, complication of parts, or extra trouble for the weaver caused most of them to be discarded. A detector is often found on these machines; it consists either of two pieces of wood placed on a level with the weaver's eye,

and numbered in large figures 1, 2, or of two tufts of

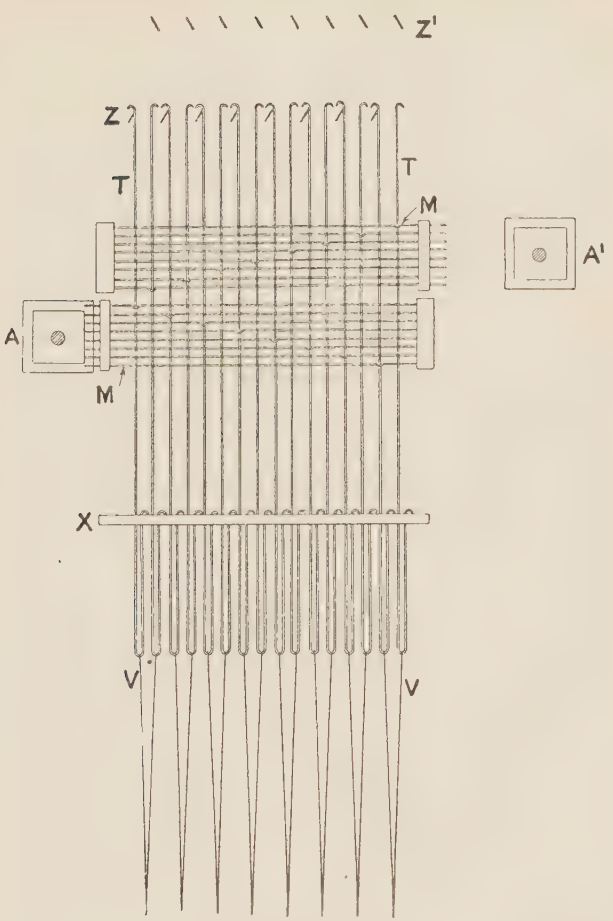


FIG. 92.

threads that differ in colour. Each is suspended by a

mounting thread from a spare hook in opposite sections of the machine, and holes are cut in the cards to lift them in succession, but at intervals of 4, 8, 12, or 16 picks. So long as the fall of number 1 is followed by the rise of number 2, the cards are working correctly, but immediately 2 rises before 1, or when an interval of one or more picks intervenes between the lifting of 1, 2 boards or tufts, the weaver knows something has gone wrong. The above plan cannot prevent faulty cloth being made. The following contrivances stop a loom when the cards go wrong.

Green and Barker's Stop Motion

In 1888 Messrs. Green and Barker patented a stop motion for double-lift double-cylinder Jacquards. They couple the neck bands of two spare hooks T, T′, Fig. 93, and carry a cord down from T, T′ to a cranked lever 43, which is so placed that when vibrated its vertical arm thrusts the starting handle from its detent and stops the loom. A pawl 44 is loosely fitted upon this arm to rest on the top of a fixed hook 45, until 43 is oscillated, when 44 and 45 engage and become locked. The loom is then incapable of running until the cards have been restored to consecutive order and the pawl lifted. A second lever 42 has a slotted head for the purpose of spanning the hooks T, T′; it receives a rocking motion from a crank pin in a wheel 46, which is driven by a pinion 47 on the bottom loom-shaft; the teeth of 46 and 47 are proportioned as 1 : 2, to move the lever 42 against the hooks T or T′ once in two picks.

The inventors state that spare holes in the cylinders A, A′, outside the cards, may be pegged to move the hooks T, T′; but this is an uncertain method, for if the cards were off the pegs either cylinder might continue to turn without

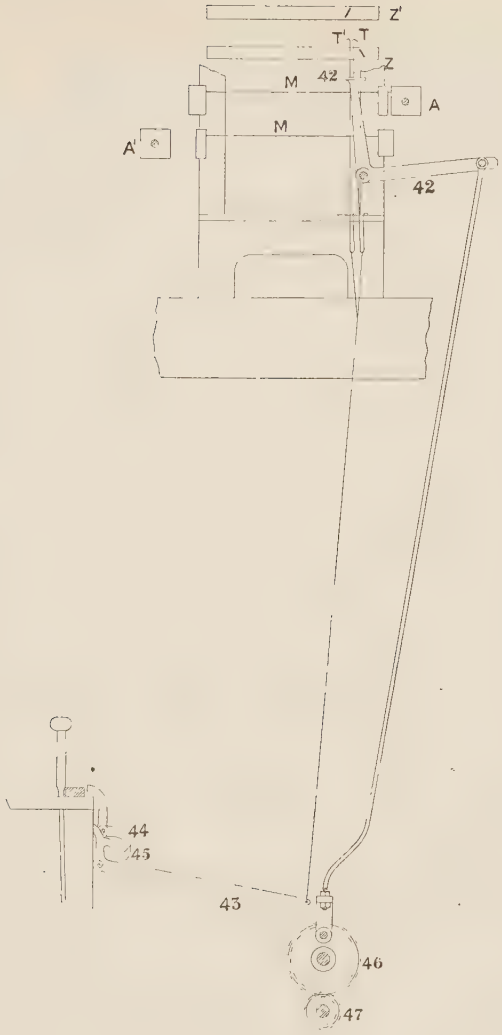


Fig. 93.

moving the cards. It is preferable to cut holes in alternate cards of each set to face the needles M, so that, if the cards are working correctly, a hole will be opposite the top needle M when the head of 42 is pushing hook T off the griffe Z, and a hole will be opposite the bottom needle M when the head of 42 pushes hook T′ from the griffe Z′. Blanks in the cards will then cause each needle to push a hook T or T′ off its griffe when the head of 42 is not acting upon it. But immediately the cards on one side get out of sequence with those on the other side, a hole in a card will face a needle when the head of 42 is not pressing back the hook controlled by that needle, and the hook will then lift and stop the loom.

Riley and Riley's Stop Motion

In 1886 Messrs. Riley and Riley patented a simple stop motion for double-cylinder machines. It requires two spare hooks at the driving side of the loom, and these must be moved by opposite griffes and needles. The hook T, Fig. 94, is furnished with a coiled eye through which the lower arm of a wire lever 42 passes ; this arm is coiled midway between its fulcrum and the hook to serve as a spring, and is loosely fitted upon a pin in the framing ; its upper arm takes into a supplementary eye in a needle M that governs a hook T′.

A spiral spring is threaded upon M, between the extra eye and the needle board N, and its office is to hold T′ off the griffe. A cord from T′ goes down to the lower arm of a lever 43, Fig. 93, which must stop the loom in case T′ lifts. A lingoe is employed to pull T down after each upward movement.

The cards are cut to stop a loom in case they are not

presented progressively; thus, every time the hook T is lifted, the needle M and hook T′ are pushed forward, and if a hole in the following card is opposite M the hook T′ will rise to stop the loom, but a blank will simply press

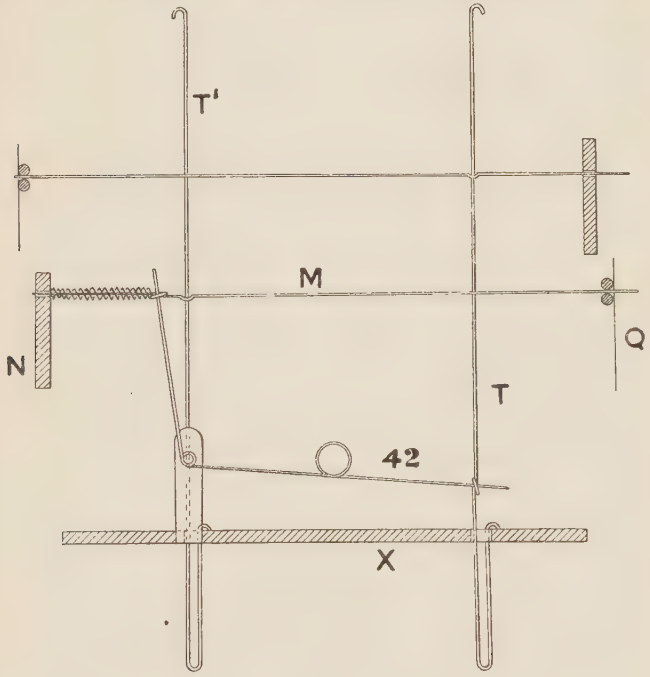


FIG. 94.

back M and T′ and bend the lever 42 at the coil. Hence a hole opposite the top needle, if followed by one opposite the bottom needle, will cause T′ to lift and the loom to stop; therefore any system of cutting can be adopted that will push back T′ while T is lifted.

For example, let odd-numbered cards be put on the top

cylinder, then, for a scheme which repeats upon 8 picks, cut holes in 1, 3, but leave 5, 7 blank. Cards 2, 4 must be blank, and 6, 8 cut. For a scheme of 12 picks to the round, 1, 3, 5 may be cut, and 7, 9, 11 left blank, if 2, 4, 6 are blank, and 8, 10, 12 are cut. In case the cards cease to rotate correctly a hole will fall opposite the needle M while hook T is lifted; T′ will then rise and stop the loom.

Open Shed Jacquards

To make changes only when changes are necessary is the ideal system of shedding, because friction and breakages are thereby reduced, and steadiness is increased; but repeated efforts to build a satisfactory open shed Jacquard have left the question in doubt as to whether the advantages of open shedding are not more than counteracted by the difficulties experienced in working these machines.

In 1877 Messrs. I. Thomis and J. Crabtree procured a patent for converting a double-lift single-cylinder Jacquard into an open shed machine. They united two hooks by one tail cord, and in the loop of the cord they placed a grooved pulley. From a plate attached to the axis of this pulley connections were made with the harness. If a griffe lifted one hook, say, 6″, the pulley axis was lifted 3″, and if for the following pick the other griffe lifted the remaining hook, the pulley was stationary, for one griffe descended as the other ascended. But to lift a griffe twice as far as a warp thread was undesirable.

In 1890 R. Wilkinson patented a method of forming an open shed without giving additional lift to a griffe. He uses a double-acting single-cylinder machine, and connects one neck cord A, Fig. 95, to two hooks B, C. The cord A passes under a grooved pulley D, and two plates E are

employed to unite D with a similar pulley F. A supplementary neck cord G is secured to one of a series of fixed

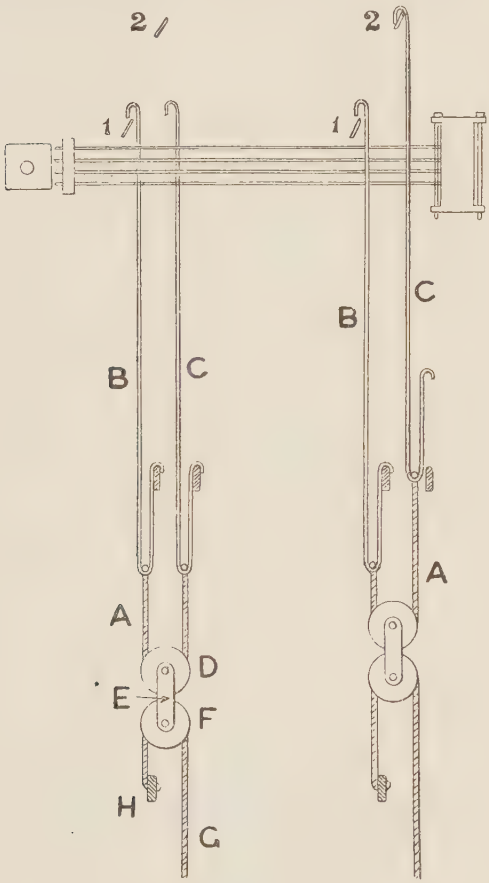


FIG. 95.

bars H, which are placed lengthwise of the machine and between alternate lines of hooks. After being led round

the pulley F, the other end of G is made fast to the mounting threads.

If both hooks which govern a warp thread are down, that thread is in the bottom shed line, but by lifting one hook it is raised to the top line, and may be retained in that position for any length of time, provided the reciprocating griffe bars lift one hook at each upward journey; for the cord given off by the fall of B is taken up by the rise of C without putting additional strain upon either machine or warp. But the neck cords A, G wear rapidly.

An open shed machine, invented in 1889 by Cheetham and Sutcliffe, is constructed on the double-lift single-cylinder principle, with needles M, Fig. 96, to move double hooks, both legs of which are 15″ long and equally bent at the top. This form has been adopted to avoid the trouble arising from the use of double neck cords. Each hook rests upon a bottom board U, through which a single neck cord V passes. At $4\frac{1}{4}$″ above U an internal bend T′ is formed on the back leg of each hook for the purpose of suspending it from a stationary griffe Z2, the latter being bolted to the end framing $7\frac{1}{2}$″ above V.

All the griffe blades are $1\frac{1}{4}$″ deep; those of the top griffe Z′ are fixed in slotted plates 11″ deep, while those of the bottom griffe Z are secured to plates $2\frac{1}{4}$″ deep. A second plate is bolted inside each end of the frame of Z and drilled to allow eight horizontal pins 1 to pass through; the pins project from opposite ends of wrought-iron plates 23, and 23 are similar in form and number to the griffe blades, but are 2″ deep. Their lower edges are parallel with, but $\frac{1}{8}$″ above and $\frac{1}{4}$″ in advance of the knives 4. All engage with projections on two sliding bars 24, only one of which is shown in the drawing, and the plates are capable of swivelling on the pins 1.

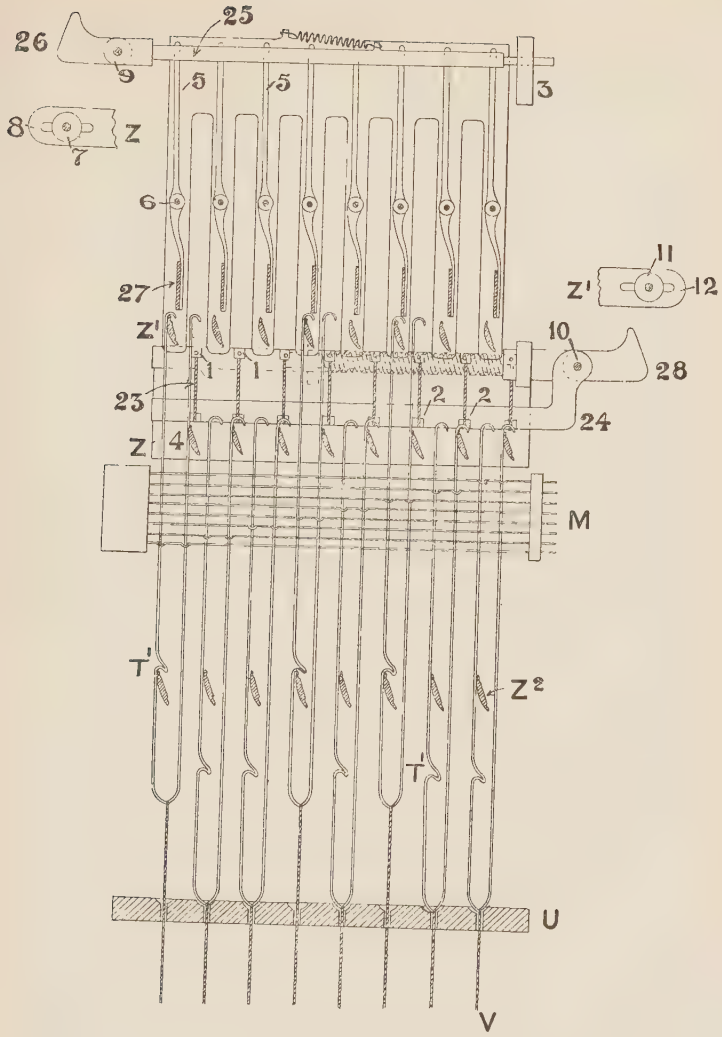


Fig. 96.

A hole is drilled in the rail 3 near each end of the upper griffe frame z′; the holes, together with brackets, hold two horizontal sliding bars 25 against the inner edges of z′. The bars 25 are drilled vertically to take the ends of eight upright iron pins 5, which are centred at 6 upon the long griffe plates of z′, and their lower ends carry a second set of plates 27, which are fixed in the same positions with relation to griffe z′ that the plates 23 occupy to griffe z.

Two swivelling pieces 26 are fitted by pins 9 to the sliding rods 25; their inclined upper surfaces are brought into contact with two antifriction bowls 7 that are free to turn upon studs secured by brackets 8 to the ends of the bottom griffe frame z. As these bowls are carried up by z, the pieces 26 turn upon their respective pins 9 and allow the bowls 7 to pass; but when the griffe z descends the pieces 26 are rigid, and the bowls, by bearing upon the inclined surfaces, force back the sliding bars 25, vibrate the plates 27, and carry their lower edges against the free heads of the falling hooks, thus preventing the rising griffe z′ from carrying those hooks up again.

Two pendent arms 12 from the griffe z′ move similar bowls 11 into contact with similar swivelling pieces 28 that project from the frame of z, and thus the free head of each descending hook is again pushed out of reach of the ascending griffe z, but this only takes place when the blades of z, z′ are level.

Each griffe z, z′ carries the catches T′ about $\frac{1}{4}''$ above the top of the stationary griffe z2; the hooks then spring over the bars and are suspended in that position until the pattern requires them to change it. At each change they are pushed off by a blank in a card and sink with the griffe that happens to be up. When the cylinder A presses a

card against the needles M, all the catches T′ are lifted above Z2, hence the force required to push them clear of Z2 is little more than that needed to press back a needle and hook in a Crossley machine. The plates 23, 27 make it a difficult matter to repair injured parts, and if a loom is turned backward they are liable to bend the hooks.

The Verdol Jacquard

Of the Jacquards specially constructed for the economical reproduction of design in fabrics there are two kinds: *a*, those intended for general use, and, *b*, those for special use. Of the machines included in class *a*, that invented in 1884 by M. Verdol is the most important. It is a small-gauge machine, in which the selecting needles are placed in zigzag lines and so close together that 896 needles only cover a space of 1″ by 11½″. This is done to economise paper and reduce the chances of it being distorted under the varying hygrometric conditions of the atmosphere. All the needles are moved by an endless band of thin paper, which is doubled in thickness at both ends and along the centre. At all thickened places peg holes are cut for pegs to draw it forward. Thirty yards of this paper are equal to 1000 cards and weigh two pounds; as compared with cards this represents a reduction of $\frac{49}{50}$. Except for accidents, the inventor claims that his paper is almost indestructible.

Several causes militate against the extensive use of this machine in high-speed looms. First, the varying humidity of the atmosphere in weaving sheds tends to rumple the paper; a defect, however, that the inventor now claims to have overcome. The remaining causes are dust, oxidation, and vibration.

In a machine so closely packed with wire and requiring such delicate adjustment, firmness, freedom from fibrous dust and rust are essential, otherwise the parts will become clogged or move unsteadily, and imperfections in the fabric will be of frequent occurrence.

A small-gauge Jacquard of the ordinary description is employed, with its needles arranged in multiples of 112 up

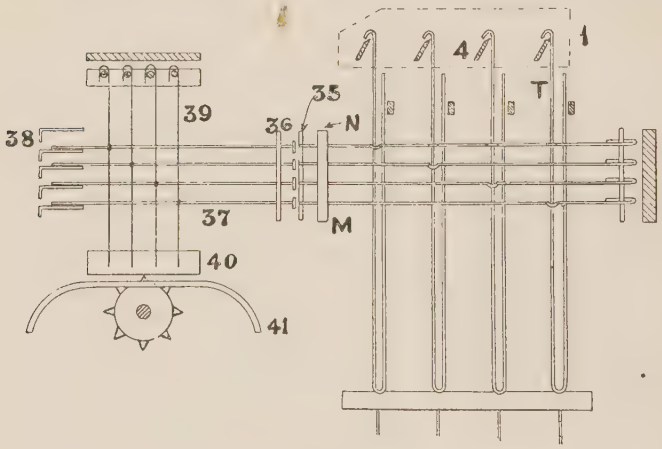


FIG. 97

to 1792. It is complete in every respect up to the needle plate N, Fig 97, but instead of a cylinder and cards, a box is made to slide to and fro before the needles M. The box contains two plates, 35, 36, and both are drilled exactly like the needle plate N; the former takes the points of M, the latter supports in a horizontal position a series of drivers 37, which are about 6″ in length. A driver faces each needle and is furnished with a disc head to render contact with M certain. At the opposite end of the box a series of rectangular parallel bars 38 are so secured as to

leave room for the rear ends of the drivers 37 to pass between, and each horizontal arm forms a support for one row of drivers.

A series of fine steel needles 39 are suspended by a hook from a slotted grid, in which they are free to rise and fall. Each is provided with a coiled eye to govern a driver 37. The vertical position of 39 is maintained by a plate 40, which is perforated in zigzag rows to the gauge of the paper and paper plate 41. All the needles 39 enter but do not normally protrude through the plate 40. A curved and perforated metal plate 41 is employed in lieu of cylinder; the paper band is passed between 40 and 41 and rotated by wheels, from the periphery of which pegs project at regular distances. The pegs pass through slots in 41 and take into peg holes in the paper. The plate 41 moves vertically through a space of $\frac{3}{16}''$ to $\frac{1}{4}''$ to force up plate 40 and move the needles 39 into contact with the paper. A blank lifts a needle and also a driver until the rear end of the latter is against the vertical arm of an angle bar 38, but a hole leaves both undisturbed.

Instead of lifting the parts 40, 41, Herm. Schroers, of Krefeld, causes the rack of bars 38, the rear ends of the drivers 37, and the needles 39 to rise and fall. An upward movement of 38 carries the needle points into the needle plate 40 before the band of paper is moved, and a downward movement of 38 makes contact between the needles and paper, hence the paper merely rotates.

Immediately the needles 39 and the drivers 37 have been actuated by the paper, the box advances against the Jacquard needles M, and where a driver is lifted against an angle plate its head will push back a needle, and therefore a hook T from the griffe Z; but where any driver is left down, its head will be pushed back by a needle M, and

its straight end will pass between the angle plates without disturbing a hook.

The vertical needles should fall by gravitation, aided in part by the weight of the drivers; still, to render sticking impossible, a trap board is brought down upon the grid to level them after every lift of the griffe. The parts of this invention can now be attached to any existing Jacquard, or they can be removed in a short time and replaced by a cylinder and cards.

Verdol's machine is in extensive use on the Continent of Europe, but unless a firm discards other makes of Jacquards, complications are likely to arise. For instance, two sets of perforating machinery will be required, and when a sheet of paper has to be cut from a design the plant is both elaborate and costly. Cost is often reduced by cutting a set of inferior cards on the piano card-cutter, after which a repeater transfers the cutting to the sheet of paper. Further, a number of sets of cards and paper bands may have been prepared for the same pattern; if half are for ordinary and half for Verdol's machines, the looms fitted with either may be required for a different class of work; there may then be a number of sets idle, and yet a demand for that pattern would necessitate cutting extra sets to suit the looms available. If all the Jacquards were of one type, trouble of this kind would be impossible. The new plan by which any Jacquard can be used with or without Verdol's attachment has, however, simplified matters in this respect.

The Electric Jacquard

So long ago as 1853 M. Bonelli attempted to employ electricity instead of cards to move the needles and hooks

in a Jacquard. At that time electricity was imperfectly understood, and its practical application was very limited. The complex nature of Bonelli's machine militated against its adoption. It required the following additions to a 400-needle Jacquard: namely, 400 armatures, 400 electro-magnets, 400 metal feelers, 800 covered wires, a battery, parts for putting all in operation, and suitable framing to support them.

In 1860 Bonelli introduced a machine details of which are given in Fig. 98, and its operation was as follows:— The feelers 49 were dropped into contact with the pattern sheet, and where they rested upon metal the electric circuit was complete, and the magnets 51 were magnetised. All such magnets, by preventing the armatures 53 from moving forward with the frame 52, drew their heads inside the plate 54. But those feelers that rested upon varnished portions of the pattern plate broke the electric circuit; and, consequently, when the frame 52 moved forward, it carried with it the armatures that faced dead magnets, and their heads remained outside the locking plate 54. In the first case this was equal to presenting perforated cards, and in the second blank cards, to the needles. The feelers 49 next rose, the pattern sheet partially rotated, and the operations were again repeated.

Patterns of two or more colours could be produced by superposing successive metal plates, each representing a different colour, and insulating them by layers of varnish. Or patterns could be composed of movable metal types, set up in the same way as printing types.

Since Bonelli placed his invention upon the market electrical science has made remarkable advances, and many able inventors have endeavoured to improve upon the original model. Several are now engaged in devising new

parts and in perfecting the actions of old ones. Amongst these the following have obtained recent patents, namely,

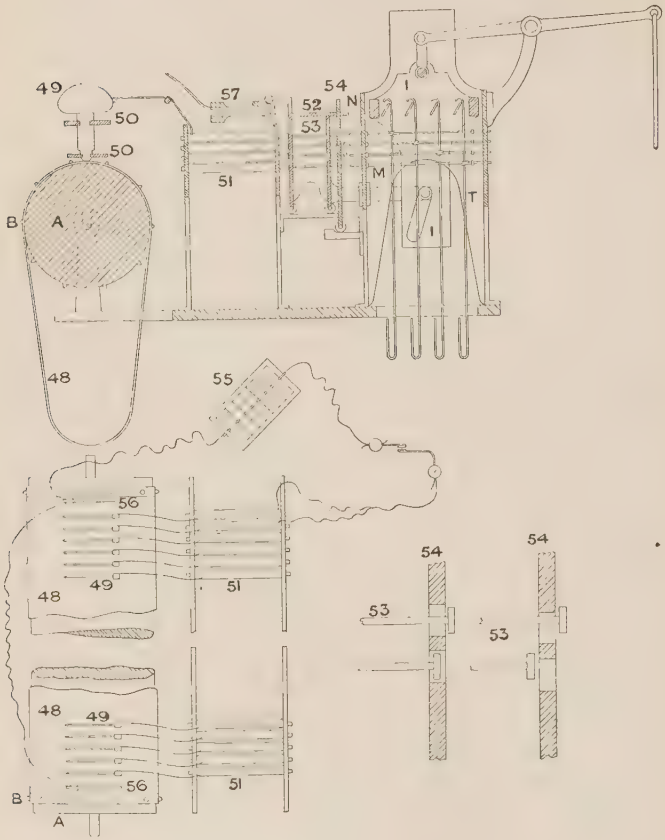


FIG. 98

Tschörner and Wein in 1887; Kauffmann in 1892; Gates in 1896; Kleinberg and Czczepanik in 1896; and Dr. Carver, who since 1896 has given the subject much

attention. They have effected improvements upon Bonelli's invention, and have apparently solved several of the problems connected with electrical selection. But although a few of these machines have been erected in mills, the inventions remain more or less in the experimental state. It is, however, probable that in the near future an electrically controlled Jacquard will be an accomplished fact.

Jacquards for Special Use

The Jacquards included in class *b* (see p. 175) are those which have been designed for the economical production of bordered fabrics, swivels, damasks, carpets, two or more ply fabrics, and many others.

A specially constructed machine is employed to manufacture fabrics with two designs that form cross stripes, and one design surrounded by a border as for handkerchiefs, table-covers, bed-covers, and towels. It effects a considerable saving in cards, as all the foregoing may be woven from one repeat of each pattern. For example, let it be assumed that the table-cover has six repeats of the body pattern; then, as compared with an ordinary machine, $\frac{5}{6}$ of the body and $\frac{1}{2}$ the border cards would be saved, for in the former two repeats of the end border and six repeats of the body and side border would be required. Or failing that, the loom would stop while the cards were changed for each fabric. Thus: after weaving the first border the body cards must be put on and they in turn will be removed for the last border. Rather than adopt such a course, however, manufacturers of cotton goods often incur the cost of a full set of cards.

Cross-Border Jacquards

In all cases where the speed of a loom is strictly limited by other than the shedding mechanism, and where single-acting Jacquards may be economically employed, cross stripes and cross-bordered fabrics may be woven with a double-lift double-cylinder Jacquard (see Fig. 92). The border cards are then passed round one cylinder and the body cards round the other. Two connecting rods are provided for the same crank pin, but only one is used at any time, and that will work one cylinder and one griffe until a change is necessary. The first rod is then removed from the crank pin and the second one placed upon it, to operate the other half of the machine and weave the second pattern. Or one jointed rod may be used as at V, W, Fig. 111. Both plans convert a double-lift machine into a single-lift, yet they avoid complications, and allow changes to be made in a short time, but they are obviously unsuitable for high-speed looms.

Another plan has been introduced by a manufacturer in Saxony, who employs two cylinders, one to swing from above, the other from below. Each swan neck forms an open fork, and when a change is necessary the griffe must be lifted until the bowl leaves the forks, then the upper cylinder can be turned up, or the lower one turned down. To disconnect the griffe and swan necks, however, an extra strain is thrown upon the warp.

In 1883 Messrs. Davenport and Crossley patented one of the best-known of these machines for high-speed looms. It is constructed with two cylinders and a duplicate set of needles. Both sets of needles move the same hooks, but when in action the machine is a double-lift single-cylinder, for one cylinder is always stationary. By passing the

border cards round A′, Fig. 100, and the body cards round A, and so connecting A, A′ that by moving a lever one stops and the other starts, any number of repeats of each pattern may be woven from one repeat of cards The hooks T, Fig.

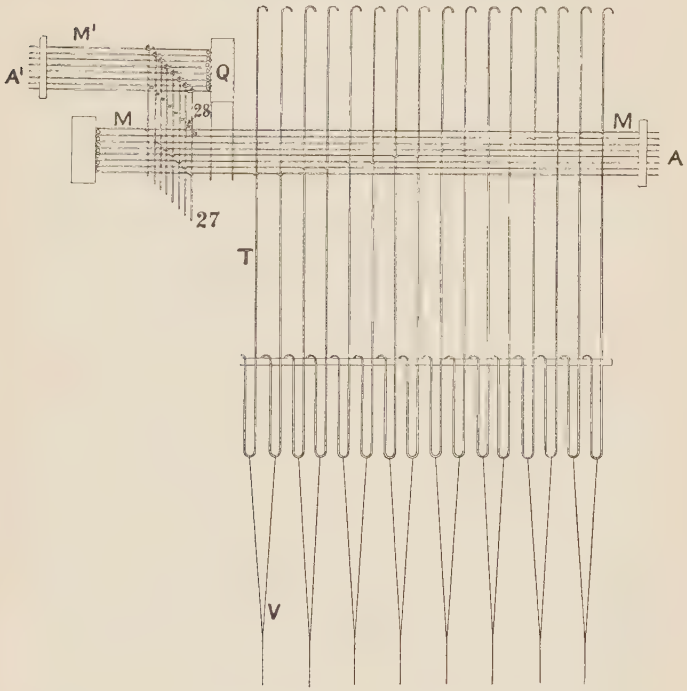


Fig. 99.

99, in a 400-needle machine are $19\frac{1}{4}''$ long. The needles M are $23\frac{1}{2}''$ long and each has an extra cranked eye. A needle M′ is 8″ long and has a coiled eye immediately over the extra crank in M. A hooked pin 27 is passed through an eye of M′, also through the extra crank of M, and is

suspended from M′ by its hook. The top row of M′ is thus connected by pins 27 to the top row of M, and succeeding rows of needles are united by succeeding rows of pins; as a consequence, if the numbered side of each card on the cylinder A faces the needles, the numbers of those on A′ must be inverted to face the cylinder, or the pattern will be spoiled.

Eight horizontal bars 28 are $\frac{3}{8}''$ wide by $\frac{1}{8}''$ deep, and long enough to reach across the machine. Each is set behind one row of pins 27 to serve as a fulcrum for all pins in one row; hence if a supplementary needle M′ is pushed back, the pin 27 will be tilted sufficiently to draw back one needle M and two hooks into the positions they would occupy if the point of M had been pressed back by a blank card. The top bar 28 is passed between the two bottom rows of needles M′, the bottom bar is between the top rows of M, and the six remaining bars are equally distributed between M, M′.

The long needles M are steadied by causing the heel-rack pins of M′ and the spring box pins Q to pass between them.

This machine contains more wire than is desirable, and the parts are difficult to repair, but it has been greatly improved by substituting flat bars 28 and hooked pins 27 for eyed pins threaded upon a fulcrum, as in Nuttall's automatic card-repeating machine, from which the idea was taken (see Fig. 154).

The cylinders A, A′ may be put in and out of action either manually or automatically; but the following device is in most general use:—A connecting rod 16, Fig. 100, a horizontal arm 17, a shaft 18, and two vertical arms 19 are all as in Crossley's single-cylinder machine; but the arms 19 are employed to rock a vertical lever whose fulcrum is at 9. The cylinder bars 7, 7′ are each slotted and

notched to receive two studs 20, 20′, which are fixed upon opposite ends of the rocking lever 9. When the stud 20 is in the notch of 7, the cylinder A is in action and the

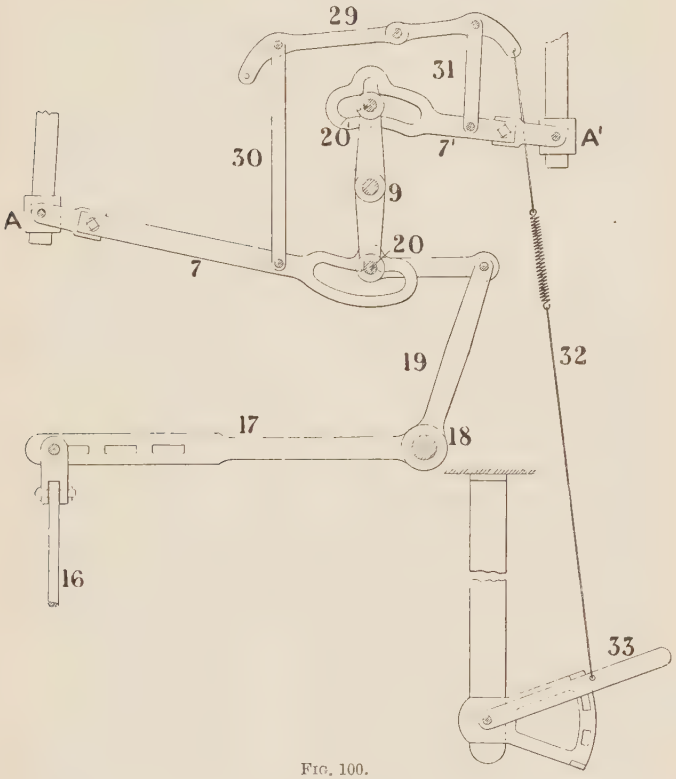


FIG. 100.

stud 20′ is in the slot of 7′. Changes are made by a lever 29 and links 30, 31. The link 30 is bolted to the arm 7, and 31 to 7′. A cord or wire 32 is secured to 29, and also to a quadrant handle 33, the latter being retained in a

fixed position by one of two projections on the quadrant face. By moving 33 to the next stop, the studs 20, 20′ change places, and the cylinder arms 7′ begin to move as the arms 7 become stationary.

A cross-border device applicable to Jacquards, invented by J. T. Whalley and introduced by James M'Murdo in 1919, is illustrated in Figs. 101, 102. The hooks and needles are arranged as in Fig. 99, but both cylinders S and S′, Fig. 101, carrying respectively the body and the border pattern cards, beat in to their needles continuously and simultaneously, receiving their motion from the rocking shaft M through the links O, O′. The slotted arms T, T′ guide the cylinders in their horizontal paths. Each cylinder is provided with two catches P, P′, one for rotating the cylinder forwards, the other for reversing it. These catches are extended beyond their fulcra and their tail ends rest on a chain of lags Q, mounted on a lag barrel J. Spiral springs R keep the catches steady. By suitably pegging the lags any of the four catches can be put into or out of gear, and the cylinders can be rotated forwards or backwards, or put out of action. One or other of the cylinders is out of action on each pick, and that cylinder then presents to its needles a fully cut card, one such card being introduced into both body and border sets (see Fig. 103).

The changing mechanism is put into operation by one or other of the needles A or B, Fig. 102, when acted on by a long card O, Fig. 103. The needles A, B are placed out of range of cards of ordinary length, and a long card O must be introduced into the set wherever a change is required.

The lag barrel J, Fig. 102, is turned, when required, by two pawls K, L, and a double ratchet I, K and L receive reciprocating motion from an arm N fixed to the rocking

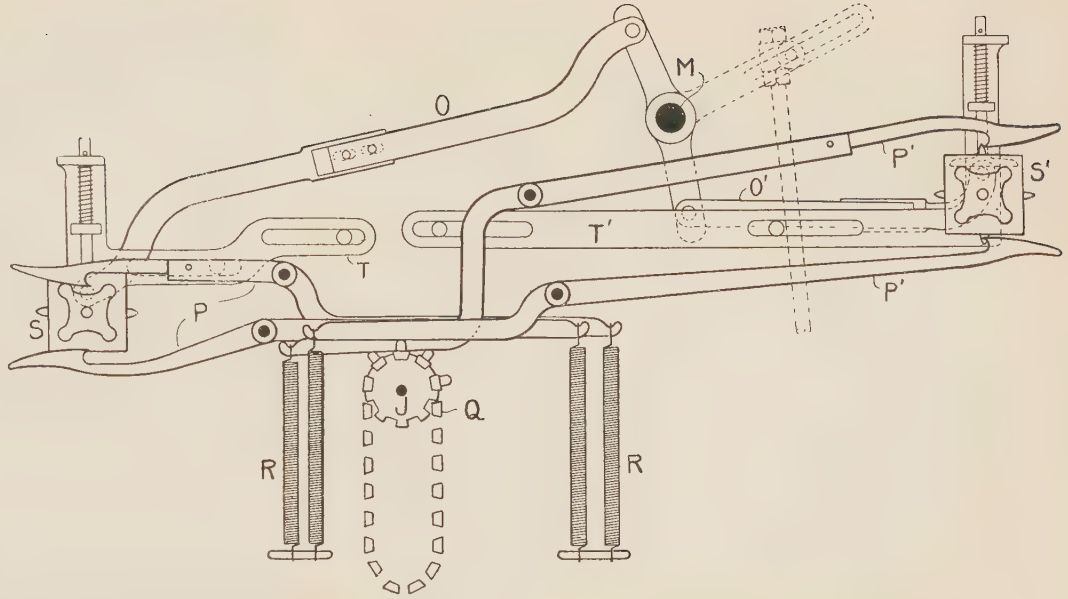


FIG. 101.

shaft M, but in the inoperative position shown in Fig. 102, K slides idly on a long tooth of the outer ratchet I, while L is kept out of contact with the inner ratchet by a plate H which is supported by one of three projecting lugs on the ratchet I.

When a change is required, a long card O acts on either needle A or B, the latter conveying its movement to A through the lever wire C, fulcrumed at D. The turned-

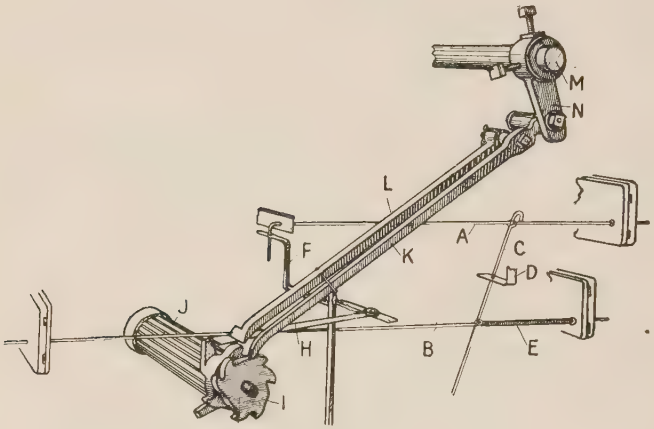


FIG. 102.

down end of A acts on the lever F which withdraws H from the supporting lug on the ratchet I, and L is lowered into contact with the tooth on the inner ratchet. L drives the lag barrel J forward one lag, and allows pawl K to come into action on the outer ratchet. K moves J forward one lag on each of the two succeeding picks, at the end of which H is lifted by the next lug on the inner ratchet, carrying the pawl L out of action and stopping the lag barrel J until the mechanism is again set in action by

another long card O. Thus J moves forward three lags every time a long card O is presented to the needles.

The arrangement of the pattern cards is shown in Fig. 103, which illustrates the lacing for a body pattern of 100 picks. Card number 100 for the last pick of the pattern is laced as the first card in the border set, being placed between the fully cut card and number 1 of the border set. This is done so that the body pattern can be repeated, number 100 being presented to the needles by the border pattern cylinder whilst the fully cut card in the body set is presented. The movements of the lag barrel and cylinders during the change would be as follows:

Pick number.	98.	99.	100.	1.
Movement of lag barrel J.	Moves one lag.	Moves one lag	Moves one lag.	No movement
Movement of body pattern cylinder S.	Turns forward. Presents card number 99.	Turns forward. Presents fully cut card.	Turns forward. Presents card number 1.	Turns forward. Presents card number 2.
Movement of border pattern cylinder S′.	No movement. Presents fully cut card.	Turns forward. Presents card number 100.	Turns back. Presents fully cut card.	No movement. Presents fully cut card.

The body pattern can thus be repeated as often as desired. To reverse the body pattern the lags would be pegged so that on pick number 100 the cylinder S turns back, presents card number 99, and continues to turn back till the repeat has been woven. The border pattern cylinder S′ would move as before.

When it is necessary to reverse a pattern in this way, whether a body or a border pattern, a second changing card O must be introduced into the set, and this would be card number 2. In that case six lags must be pro-

vided every time that pattern is woven, since each of the two long cards 0 requires three lags. Only one of these sets of three lags is used for the change; the other three lags must all be pegged the same so as not to affect the movement of the cylinders.

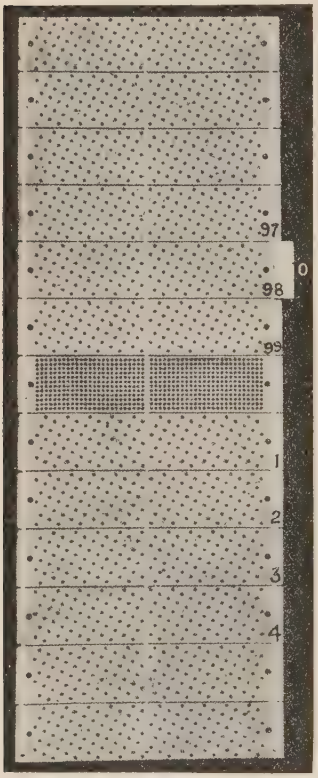


FIG. 103.

The long cards 0 are unable to pass through the card cradle, but a neat arrangement of card wires is provided which keeps these cards folded on the top of the cradle.

TWO PATTERNS ON ONE SET OF CARDS

Two patterns are sometimes cut on each card, the first on odd-numbered rows of every card, and the second on even-numbered rows. In such a Jacquard alternate rows of needles are removed. A motion may be attached to the cylinder or cylinders, or the needle plate may be moved automatically in a manner resembling one of those described for a decked dobby (see pp. 84, 92). After weaving as many repeats of pattern one as are required, either the cylinder or the needle plate is moved and pattern two brought to face

the needles. If eight repeats of one and two repeats of the other pattern are necessary, the economy effected consists in using one repeat of cards, doubled in width, but of the usual length, instead of $8+2=10$ repeats of single-width cards. Only patterns containing an equal number of picks to a repeat, or those in which one is a multiple of the other, can be produced by this plan.

In 1900 Walter Paton patented a cross-border Jacquard having two cylinders fitted upon the same side of the machine, one to stand farther out than and above the other. The bottom cylinder A, Fig. 104, carries the body and side border cards, and the upper cylinder A′ carries the end border cards. A acts through double-cranked needles M, upon two hooks T, each of which is 27″ long, in the same manner that the cylinder of a Crossley machine acts, and two hooks are united by neck cords V to operate one warp thread. A′ acts upon a separate set of needles M′ to control the same hooks as the needles M. Each needle M′ has for eyes two long cranks, which permit M to press back the hooks without obstruction. Yet the front of each crank in M′ is available for operating a hook in the usual manner.

One cylinder may be put in or out of action by a similar plan to that illustrated in Fig. 100; or automatic mechanism may be employed. In either event the efficiency of the machine will be largely determined by the mechanism for operating the cylinders. In other respects the machine is simple and, except that the top needle M is 10″ from the hook head, the design is satisfactory.

The cord machine (see pp. 151, 152) was altered in 1889, by H. Fawcett, to weave cross-bordered fabrics. In order to accomplish this he made the needles straight at both ends and to project beyond two needle plates. One

cylinder controls the side border and body cards, the other those for the end border. When one cylinder is in action the other is away from the needles and inoperative. The trap board has a saw slit on each side of every hole, hence, other things permitting, a cord will enter a slit no matter

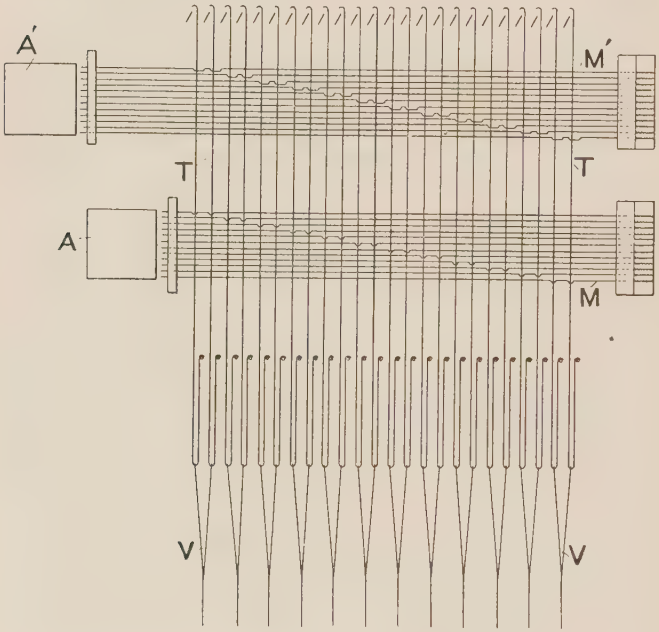


FIG. 104.

which end of its needle is pressed back. After each card has been presented, a batting board restores the needles to their normal positions, and since there are two cylinders there must be two boards. But immediately before a set of cards is changed one board is moved vertically out of reach of the cylinder which is to become active; the other

is moved level with, and between, the needles and the stationary cylinder. Beneath the trap board a species of grid is fitted horizontally ; its bars are parallel with, and enclose, the neck cords. By moving this grid laterally whenever a change from border to body or body to border cards has to be made, one set of slits in the trap board will be closed, but the other set will be left open for the cords to enter. In order to clear the cords from the slits, the suspension board, the trap board, and the bottom board all move laterally for each pick.

Double Shed Jacquards

Jacquards have been built to weave fabrics that require two picks of weft, or one weft and one wire, to be superposed, both being simultaneously passed through separate sheds in the warp. In the case of swivelled fabrics, the lower shed receives ground weft, and the upper one swivel weft.

Messrs. Howarth and Pearson, in 1868, constructed such a machine with the object of doubling the production of a loom. The device is shown at Fig. 105. This machine makes imperfect cloth, because the ground weft floats under the figure in precisely the same manner as swivel weft.

In the manufacture of pile fabrics, where wires are woven into the pieces in the same manner as weft threads, and subsequently withdrawn or cut out, a loom is furnished with a compound harness, consisting of healds for controlling the ground warp and a Jacquard for controlling the pile warp. Two sheds are opened simultaneously, one to receive a shuttle, the other a wire. The healds form a single shed, but the Jacquard forms a double one. This is done by using hooks which are approximately 27″ long,

and by lifting them from two places. Thus the grid has a sufficient vertical movement imparted to it to carry all the hooks to the top of the first shed, and the griffe moves far enough to carry a selected number of hooks to the top of the second shed. Both grid and griffe are moved by cams and levers in the usual manner.

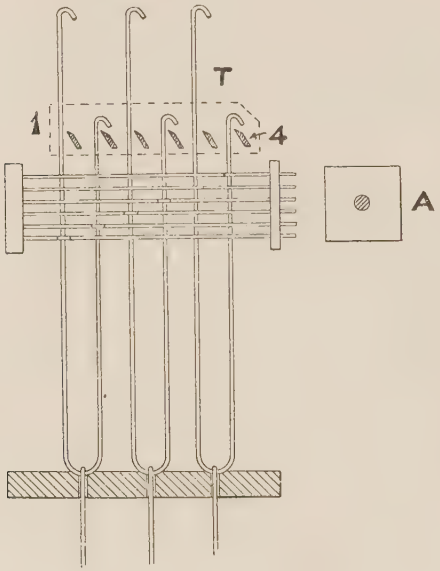


FIG. 105.

Instead of the foregoing, a cord machine (see pp. 151, 152, and 191) may be employed in conjunction with healds. In that event a knot is tied upon every cord on a level with the upper face of the bottom board, and a vertical movement, equal to the depth of the bottom shed, is given to that board. Meanwhile the trap board carries up a number of cords to form the second shed.

Compound Jacquards

Certain compound fabrics whose figured effects depend solely upon colour are made by the aid of Jacquards having two sets of hooks to one set of needles and cards, as in Fig. 106. All hooks moved by the griffe Z are placed in succeeding rows to face the cylinder, and lift when vertical; while all hooks moved by Z′ face the spring box, and are left down when vertical.

Each needle M governs two hooks that occupy corresponding positions in both sections of the machine. But succeeding needles in one vertical row do not govern succeeding hooks. It will be noticed that needles 1 to 8 respectively control hooks 1 and 9, 5 and 13, 2 and 10, 6 and 14, 3 and 11, 7 and 15, 4 and 12, and 8 and 16. This is done to avoid crossing the harness at the comber boards, for the neck cords from the first four hooks are connected to successive couplings in the comber board No. 1, Figs. 127, 128, and those from hooks 5 to 8 are attached to couplings in board No. 2. Hooks in the second section of the machine are similarly connected to couplings in boards 3 and 4. The griffe Z governs one warp, Z′ another. The cylinder and griffes have separate actions and only move once in two picks. Thus while A presses a card against the needles M, the griffe Z rises with the vertical hooks T. If one warp is blue, the other white, threads of blue will be lifted by Z, and a pick of white weft will be passed between white warp threads in plain or twill order. But the white threads are lifted independently of the Jacquard, as explained on pp. 243 to 246. Z then sinks, and Z′ in ascending takes with it the white warp threads that occupy positions corresponding with those of the blue warp previously left down by Z, and blue weft is passed through

a plain or twill blue shed, also formed independently of

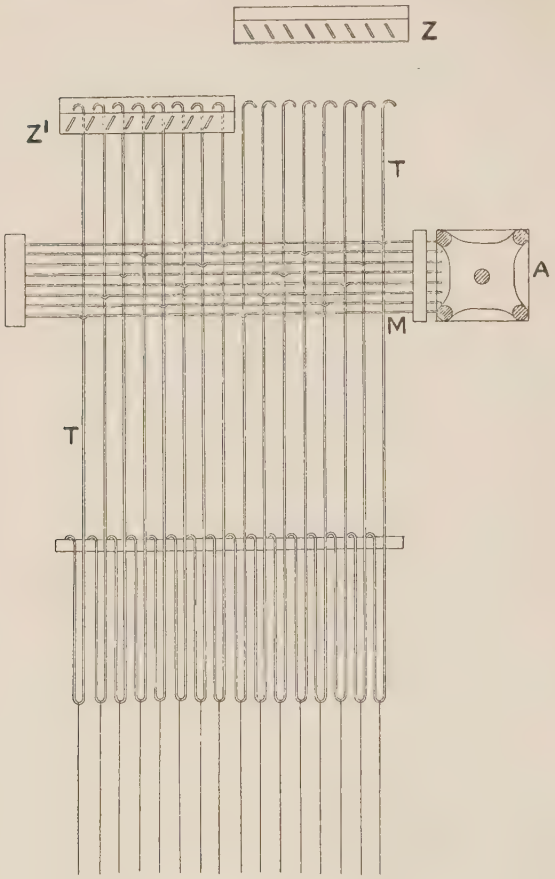


Fig. 106.

the Jacquard. During this time card 1 has remained pressed against the needles, but the cylinder A now brings

card 2 into contact with the needles, and the foregoing process is repeated.

This machine is excellent for the work it is capable of doing, but its application is necessarily limited.

Scale Jacquards

Scale harnesses (see pp. 246 to 253) preceded scale Jacquards by many years. But at the present time there are several machines which do similar work to that formerly done by harnesses. The machines possess advantages over a harness whether the shafts are placed below the comber board, or slightly below the bottom board of a Jacquard. In Fig. 107 two vertical sections A, B of a scale machine are shown. In section A each figuring needle M is seen to govern two adjacent figuring hooks T, and the tail of each hook rests upon a twilling bar C, which is in turn supported by a grid D. The twilling bars C are laid at right angles to the needles, and each can be lifted at pleasure to cause a line of hooks to rise. This is done by adding an extra hook T′, section B, to each end of every row of figuring hooks. A hook T′ has a coiled eye at G for the reception of one end of a twilling bar C. By lifting a corresponding hook T′ at each end of the machine, a twilling bar will carry up all the figuring hooks T in that line. Outside the space allotted for figuring needles M, two small sets of cards are placed upon the cylinder H, and these are cut to lift single threads of warp to bind ground portions of the fabric, while the large cards weave the figure by lifting contiguous warp threads in pairs. Beneath the coil G, the twilling hooks T′ are straight and are passed through guide holes in the grid D. In the drawing each needle M′ actuates two twilling hooks, hence any ground weave made by this machine

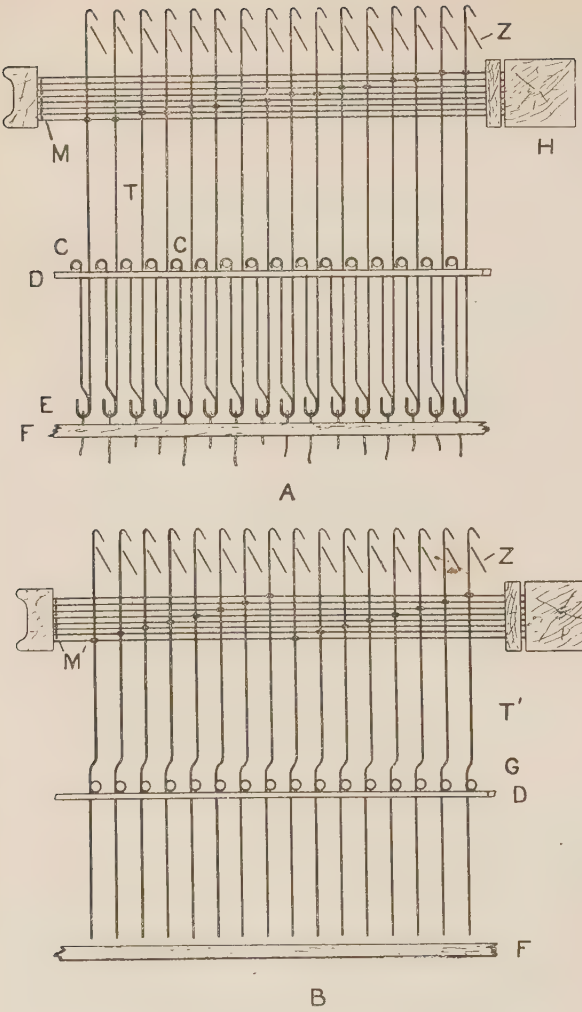


Fig. 107.

must repeat upon 8 threads. But by using two rows of needles at each end of the machine every twilling hook may be put under separate control, and patterns of 16 threads to a repeat may be woven. Also, each figuring needle M may control three or four hooks T, and by so doing a design will be made three or four times as large as it could be made with an ordinary Jacquard. The base of each hook T is bent to facilitate the attachment or detachment of a harness. See also K, Fig. 118.

Twilling Jacquards

Where large patterns are to be made from closely placed warp, the cost of employing ordinary Jacquards of sufficient capacity is almost prohibitive, especially now that most patterns have a short run. Inventors have endeavoured to solve the problem of reducing the number of cards, by devising special harnesses, and by constructing special Jacquards. It is the latter that will be dealt with here.

In 1859 J. Shields invented a machine that was capable of lifting and leaving down warp, irrespective of the perforations in a card ; also of making one card serve for two or more picks. The idea has been developed by several succeeding inventors, of whom Barcroft, and Tschörner and Wein, have devised the best-known plans.

The Bessbrook Jacquard

The "Bessbrook" Jacquard was invented by H. Barcroft in 1869, and is applicable to textures in which the entire fabric is bound together by a twill, a satin, or some other regular system of interlacing.

The action of the cards is to lift all warp where

figure is to be formed, and leave it down where ground is required; this would not produce a useful texture. Parts are therefore added to prevent one thread in each repeat of the figure binding weave from rising, and to lift one thread in each repeat of the ground weave. Even this is inadequate; one needle must actuate two, three, or more hooks, and one card must suffice for two, three, or more picks. The advantages of a twilling machine over an ordinary Jacquard will be apparent if it is assumed that a machine of each kind has 400 needles. Then if a twilling machine with three hooks to one needle gives three picks to one card, the warp threads to one repeat equal $400 \times 3 = 1200$, or a range equal to that of three ordinary 400-needle Jacquards; but the latter would require three cards to one pick, instead of three picks to one card, or nine times as many as a Bessbrook. There are other advantages; for instance, a considerable alteration in the closeness of the weft threads would distort an ordinary pattern, but with a Bessbrook machine such an alteration would merely require more, or fewer, picks to each card, in proportion to the alteration; thus, instead of three picks to a card, two or four could be inserted, or again, two for one and three for the next card. Changes in the closeness of warp threads would require two hooks to be moved by one needle, three by another, or four by all; but with a given count of reed the greater the number of picks to a card, and hooks to a needle, the more irregular the outline of a figure becomes.

There have been several modifications of the Bessbrook, but the leading idea in all has been to lift each hook at pleasure from two places, and for each pick of weft to move two or more griffe bars from an inclined to a vertical position, so that entire rows of hooks shall be left down;

also to cause hooks in the rows adjacent to the vertical blades to be lifted, whether a card has acted upon them or not; at other parts of the machine, only vertical hooks will rise.

The inventor accomplishes these things as follows:—A hook T, Fig. 108, is 15″ long, and a closed loop is formed

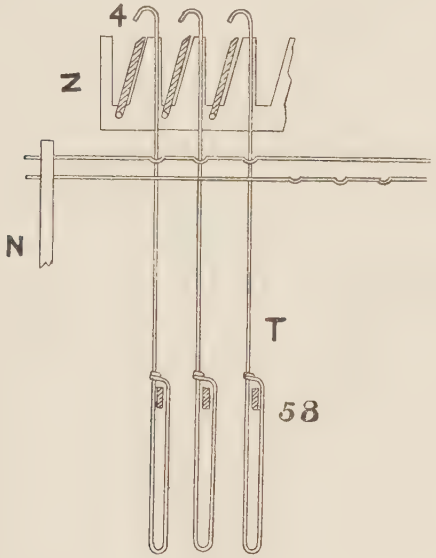


FIG. 108.

at the bottom by twisting the end of the short leg round the long one; the length of this loop must exceed the depth of a shed. When not in action the hooks in each row are supported by a bar 58, which passes through the loops and rests in a slotted framing 59, Fig. 109. A hooked rod 60 is attached to each end of every bar; it rises to the level of ordinary hooks, and is supported by,

but held back from, the griffe Z by a needle M′. The needles M′ are 16″ long, and have a collar 61 upon each. An open spiral spring is threaded upon each needle to impinge against the needle plate N and the collar 61.

The griffe frame Z, Fig. 108, is slotted to receive and limit the angular movements of the blades 4. The basal ends of 4 terminate in pins that enter holes in the griffe frame, and each blade can be turned from an inclined to a

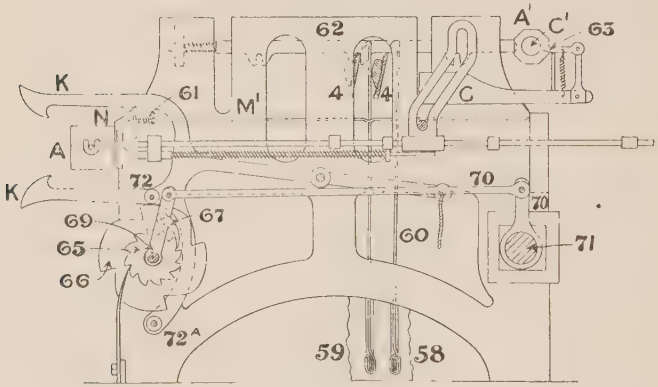


Fig. 109.

vertical position. Two or more blades are moved simultaneously by flat bars 62, Fig. 109, which have notched projections on their lower edges. Each bar 62 is cylindrical at one end, to receive a spiral spring, and that end is passed through a perforated plate, but the other end is flat and works in a grid. Immediately in front of the flat ends a pegged cylinder A′ is placed parallel with the cylinder A, but at the opposite side of the Jacquard. A′ is fixed in bearings in the griffe block; it moves up and down with the griffe, and is turned $\frac{1}{8}$ of a revolution for each pick

by a finger 63 that is free to be lifted, but cannot be depressed. A lantern C′ is attached to one end of A′ and when it strikes the finger 63 the cylinder moves, causes a fresh set of pegs to bear against the ends of the twilling bars 62, and the bars place certain blades out of reach of their hooks. Two curved pieces of brass are secured upon each blade to face the thick hooks 60. As a blade is turned up the brasses move two hooks 60 over an adjacent sloping blade, close two spiral springs 61, thrust forward two needles M′, and cause a bar 58, with all the hooks it controls, to be lifted at the next upward movement of the griffe. In order to operate the last pair of hooks 60, two brasses are mounted upon a swivelling piece placed behind the back row of hooked rods.

The cylinder A receives a sliding motion from a pair of swan necks G, which are bolted upon side shafts, but the double catch K only turns it when required. K is operated by compounding a ratchet 65 with a tappet 66, and fitting them upon a stud. The ratchet is moved one tooth for each pick by a pawl 67, and 67 is held in the teeth of 65 by a spring. The pawl is fulcrumed on an arm 69, which is in turn centred upon the tappet stud, and connected by a rod and lever 70 to the vibrating griffe shaft 71.

A bowl 72 is secured to the lower leg of the catch K, and rests upon the tappet 66. An elevation on the latter holds both legs of the catch free from the lantern of the cylinder and prevents A from turning, but a depression in 66 brings either the top or bottom leg into contact, therefore the shape of the tappet 66, and the number of teeth in the ratchet 65, determine how many times the same card shall be presented to the needles.

This cylinder may be worked forward or backward at

pleasure, for a third arm from the catch K also carries a bowl 72A, which is controlled by the tappet 66. 72A may be put into or out of action by attaching a weighted cord to the rear end of the catch lever. If this weight is upon the lever, the lower catch K will act, but if the weight is supported upon the loom framing, the upper catch K will turn the cylinder.

When the barrel A′ is pegged to produce the desired weave, the twilling bars 62 will turn two or more griffe blades vertical for each pick, and push corresponding hooked rods over adjacent slanting blades. The cylinder A presses a card against the needles, and the griffe Z in rising lifts all vertical hooks except in those rows where the blades are vertical, and also all hooks in those rows where the thick hooks 60 have been pushed over the griffe, for the latter are lifted from the bottom loops by the bars 58. A pick is passed through the shed, the griffe Z descends, the barrel A′ is turned, other twilling bars and thick hooks are moved, and, although the same card is pressed against the needles, the griffe goes up with a fresh set of hooks.

The number of rows of hooks and needles depend upon the number of picks to a repeat of the binding weave, also upon the number of hooks governed by one needle. For example, the needles of a 400 machine, if arranged for an eight-thread satin, may each have two, three, or four eyes; in which case there would be 16, 24, and 32 rows of hooks respectively. But if arranged for a ten-thread satin, the needles would have two and three eyes alternately, and there would be 20 rows of hooks.

A Bessbrook Jacquard is not adapted to the simultaneous production of ground binding weaves, which differ from the figure binding weaves. In this respect it is inferior

to a pressure harness (see pp. 250, 253). But a Jacquard invented in 1887 by T. Tschörner and K. Wein enables one weave to be wrought in the ground and another in the figure. Its essential features consist in mounting each griffe blade A, Fig. 110, and each twilling bar B in separate frames, and in lifting each independently by a rod. The rods are attached to jacks placed over the Jacquard, and the jacks are moved in one direction by tappets at the end of a loom, but springs provide the opposite movement. Both ends of the machine framing are slotted vertically in two lines, so that projecting lips, from the griffe frames, may pass through the upper slots; similar lips from the twilling frames B pass through slots in the bottom line. By this means both sets of frames are moved vertically. Each undisturbed blade A provides binding points for the figure, and each lifted bar B provides those for the ground. The hooks E are made of flat sheet-iron, cut to the required shape, and projecting lips F permit those in one line to rest upon a twilling bar B. The needles K may have several eyes coiled one behind another, or they may be cranked alternately to right and left so that the needles in one vertical line shall govern two rows of hooks from front to back; also, one needle may govern more hooks than another, as in the Bessbrook machine.

A card N equals several picks, but during the time it is in use the cylinder remains away from the needles and stationary. A griffe blade can only lift vertical hooks, yet the needles may push some back in every row. But when once lifted, all the griffe blades except those required for binding remain stationary until a card is changed, at which time all sink to the lowest point. In weaving an eight-thread satin at least seventeen tappets are needed—eight for the griffe blades, eight for the twilling bars, and one

for the cylinder. Seven of the griffe blades and one twilling bar rise for the first pick, and the eighth blade

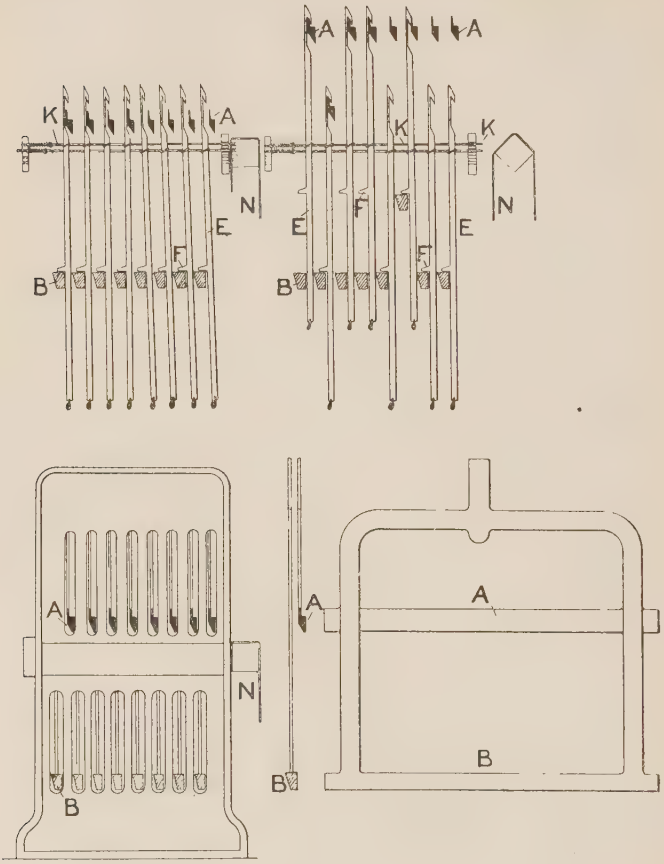


Fig. 110.

rises far enough to engage the heads of the vertical hooks in that line. For the next pick this blade rises and another sinks, but not far enough to liberate its hooks, for

those hooks must be again lifted for the succeeding pick; a fresh twilling bar is lifted, and the first one sinks. In a similar manner provision is made for the formation of different open sheds from the same card.

Jacquard and Harness Lifts

The griffe of a single-lift Jacquard is generally actuated by fixing an eccentric or a crank A, Fig 111, upon the main driving shaft B, and connecting A by a long rod C to a lever D above the griffe E. But since such an arrangement of parts does not give a dwell sufficiently long to allow a shuttle to move across the loom, it becomes necessary to pick before the griffe has reached its highest point. Thus, if the lifting crank is 45 degrees in advance of its bottom centre as a shuttle enters the warp, when it reaches a point 45 degrees past that centre, the shed, although closing rapidly, will be as deep as when the shuttle entered. But little more than $\frac{1}{4}$ of a pick is available. By securing the upper end of a short rod from the crank to a lever fulcrumed at a height of from 12″ to 18″ above the crank centre, and by connecting this lever by means of a second rod to the griffe lever, a considerable additional pause may be obtained. For the effect of shortening a connecting rod, see Beating Up, Part XVI.

The griffes of a double-lift Jacquard are usually actuated from a double-throw crank F, which is fitted upon the bottom loom-shaft G. From the cranks motion is conveyed by two rods H, I to two levers J, K, placed above the griffes L, M. A single cylinder is vibrated, as on pp. 156, 158. But two cylinders are moved from the bottom loom-shaft by an eccentric O, a rod P, a shaft Q, an arm R, two arms S, and two adjustable bars T, the latter being

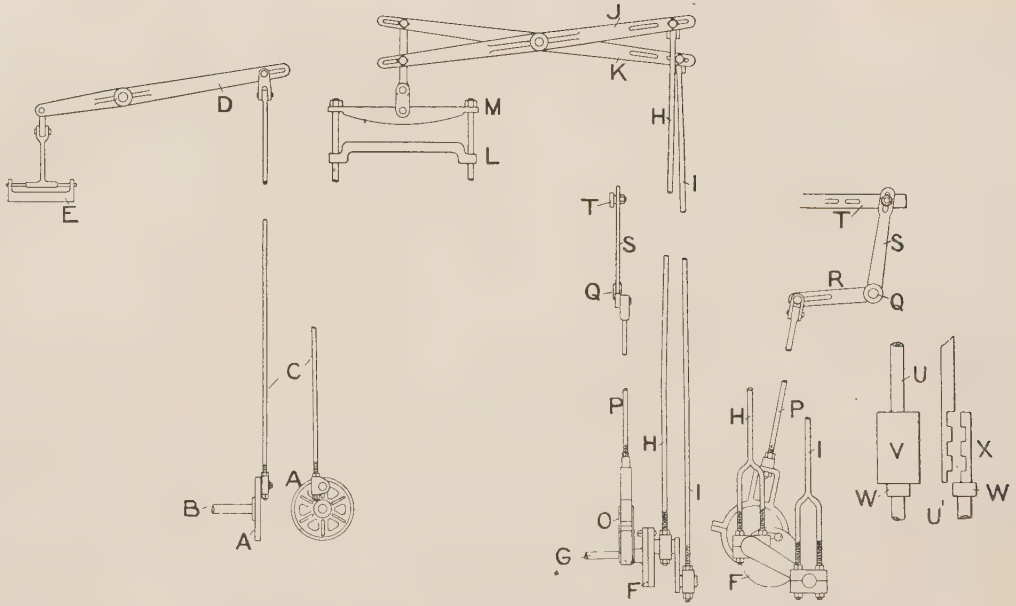


Fig. 111.

made fast to the battens of the cylinders. The double-throw crank is set with its pins in a vertical plane when the slay cranks are slightly past their bottom centres, and when the cylinder crank is near its front centre. When the slay cranks are on their top centres, the griffe cranks are horizontal, and the shed is half open, but at the beating-up point the griffes are forming a shed for the following pick.

A double-lift double-cylinder Jacquard, if used to weave cross-bordered fabrics, may have a single crank on the top loom-shaft to operate a rod U′, with a collar W set-screwed upon it. But two rods U are fitted upon the griffe levers, one of which is always inoperative. Either rod can be used at pleasure, for they are broken at X and the ends are toothed. The teeth of one rod U may be made to engage those of U′ by slipping a loose boss V upon U, and when U, U′ are united the boss is dropped upon the collar W as shown at V, and will prevent the pieces from becoming disconnected until V is again lifted.

Although the foregoing methods are largely used, cams are often preferable, for they can be shaped to give any length of pause and any velocity of rise and fall. For fabrics in which one card equals two or more picks, either negative or positive cams are almost indispensable.

Fig. 112 shows the construction of a cam suitable for a fabric having 4 picks to 1 card. During the insertion of those picks the Jacquard griffe remains stationary at the top, but between picks 4 and 5 it sinks, and, after a fresh selection of hooks has been made, it rises again in time for pick 5.

Let it be assumed that a space of 3″ separates the centre of a cam stud from the smallest part of its surface, also that the lift is 3″. If the dwell is $\frac{1}{3}$ of a pick, the time for

making changes is $\frac{3}{32}$ of a pick; this time may be divided into twelve parts as follows: Four for sinking the griffe, two for making changes, and six for lifting. The cam is further assumed to act on a treadle bowl 2″ in diameter.

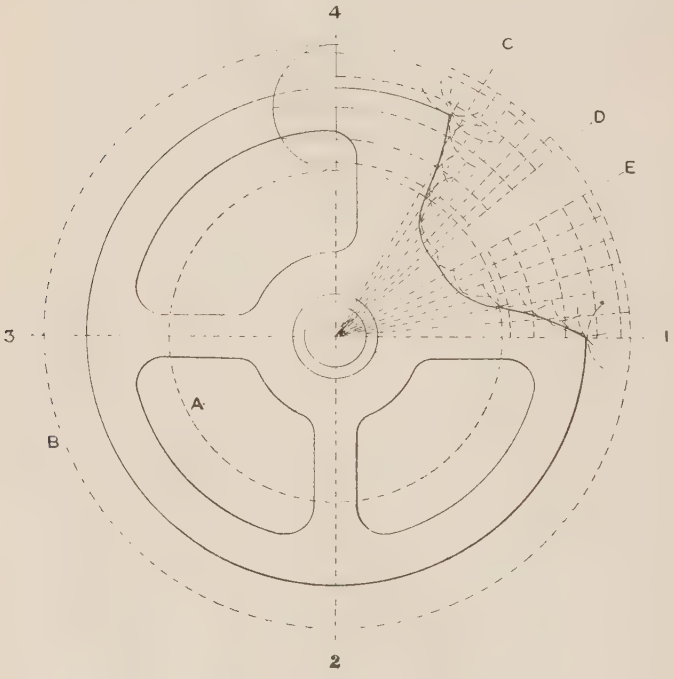


Fig. 112.

To construct such a cam, describe a circle A equal in radius to the distance between the centre of the anti-friction bowl and the centre of the cam stud when that bowl is in contact with the smallest surface of the cam, namely, 3″ + 1″ = 4″. Add to this the lift of the cam, and

describe a circle B = 7″ radius. Divide the circles A, B by radial lines 1, 2, 3, 4 into four equal parts, each part to represent one pick. Next divide any space, say 4 to 1, into three equal parts, and use 4C, which equals $\frac{1}{3}$ of a pick, as dwell. Divide the remaining two-thirds into twelve equal parts, take the first four, C, D, for sinking the griffe, allow the two following parts, D, E, for making changes, and employ the remaining six, E to 1, in lifting the griffe.

Next divide A, B into any number of unequal parts, as explained in Tappet Shedding, p. 41, say six; then subdivide C D, E 1 respectively into the same number of equal parts, and use successive points of intersection as centres round which the friction bowl circles are to be described. Trace a thick line that touches the periphery of each bowl circle, and continue it round the divisions 1, 2, 3, 4C with compasses. Cams of this description are generally driven by wheelwork from one end of the crank shaft, and the cam treadle is connected to the lifting rod.

When the number of picks to each card is uniform it is customary to employ cams to move comber boards (see Figs. 125 to 128) as well as the Jacquard griffe. In case the number of picks to the weaving scheme is too large for a cam, as 18 or 24 picks to a repeat, various devices are employed to operate a harness. One is illustrated in Fig. 113. By its aid a Jacquard selects the board to rise, but a cam of 3 picks to the round is employed to lift it for an eighteen picked weave, and one of 4 to the round for a twenty-four picked weave. A is a spare hook in the Jacquard which is connected by a wire to a cranked lever B, and by a second wire to a draw rod C. This rod is attached to the tappet treadle D in the usual manner; but instead of being fast upon the jack E, it passes through

a slotted bracket F, which is bolted upon the jack. C has a catch formed near the top; it is held back by a helical spring G until the hook A is lifted; then as the lever B vibrates, the catch on C is drawn over a solid part of the plate F, and retained in that position until the treadle D is next depressed, when the rod and jack lift the board. So

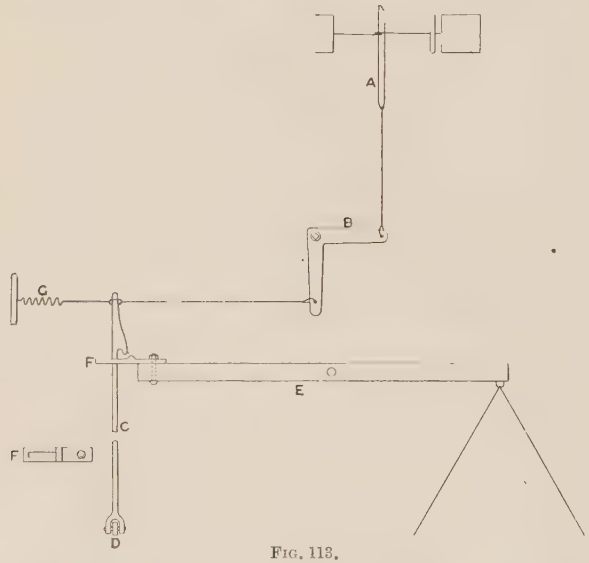


FIG. 113.

long as the hook A remains unlifted, the rod C may be drawn down by the tappet and treadle D any number of times without affecting a comber board. Similar parts are required for each board.

When there are more picks to one card than to another, the accompanying method may be adopted. A, Fig. 114, is a winged tappet fitted upon the bottom shaft of the loom and capable of acting upon an antifriction bowl B to depress

a treadle C every pick. C is fulcrumed at D, slotted at E to permit of a connecting rod F being attached, and is passed through a slot in an upright G. A cranked lever H is fulcrumed upon G, and its vertical arm is shaped to form a latch at I, while its horizontal arm is placed beneath either a tappet or a lag barrel J ; the latter is moved every pick by wheel gearing or by a pawl. If free to act, the

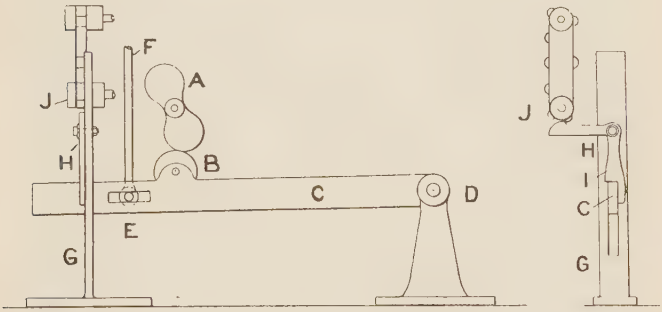


FIG. 114.

tappet A would depress the treadle C every pick, but when once lowered the upper edge of C is about $\frac{1}{8}''$ below the catch I, and is prevented by I from rising until the horizontal arm is pressed down by a peg on the barrel J. The slight movement given every pick to the treadle C, by the cam A, permits of the cranked lever H being moved with freedom. By suitably pegging the lags a Jacquard griffe can remain up for any length of time, but after each movement of H a card is changed.

PART VII

THE FIGURING HARNESS

THE Jacquard machine operates a figuring harness more economically than any plan previously used, but the harness was employed for centuries before Jacquard's birth. It consists of couplings, comber board, and mounting thread. A coupling includes a lingoe, a mail, and one loop, or two loops of linen thread; or it may be made entirely of wire.

A lingoe is a dead-weight suspended from the end of a coupling to keep the harness twine in tension. It is made from cylindrical wire or lead, flattened and punched at one end to take the lower portion of the coupling twine. Or if for wire couplings, a lingoe may be pointed at the top and bent to form a loop. A lingoe varies in length from 7″ to 19″, and in weight from 4 to 60 to the pound, but for average cotton goods 20 to 30 to the pound is usual. If a weaving room is damp, corrosion may be prevented by coating the lingoes with a vitreous enamel, or by electro-plating, galvanising, or varnishing them. The lower coupling loop connects a lingoe and a mail, and is from 6″ to 9″ long to permit the Jacquard hooks to lift without carrying lingoes amongst the warp.

Mails are made of brass, copper, steel, galvanised iron, or glass. Some have from two to five eyes for the warp, but as a rule they contain three holes, a small one near each end and a larger one in the centre. Both outer holes receive coupling twine, but the middle one is reserved for warp. An upper coupling loop varies in length to suit the position of the comber board and its place of connection

with a mounting thread. If a coupling and a mounting thread are to be united above a comber board, the loop is from $12\frac{1}{2}''$ to $16''$ long. But if below a board, $6''$ to $9''$ will suffice. If a wire heald forms the entire coupling, it is customary to connect it below a board.

A comber board is usually made of wood and perforated to hold each mail exactly opposite the reed dent through which its warp thread has to pass, but there are several kinds :—

(*a*) A piece of wood which is $\frac{3}{4}''$ to $1\frac{1}{2}''$ thick, long enough to reach across the loom, and wide enough to take as many holes as are required in one short row. The use of such a board is optional or essential according to the class of fabric to be woven.

(*b*) Boards composed of wooden slips from $\frac{1}{4}''$ to $\frac{5}{16}''$ thick, by from $1''$ to $3''$ broad, and held together in a grooved frame, are most used; although earthenware, glass, and enamelled iron have been tried. For general work slips possess advantages over other comber boards, as they are capable of adjustment before tying up, and also to a slight extent afterwards. Thus, if slips are held apart with strips of wood, a harness will be suitable for a coarser and wider reed, provided the alteration does not necessitate an over-all movement of more than $1\frac{1}{2}''$. But if, after a harness has been built, the slips are opened out more than $1\frac{1}{2}''$, the outside mails will be lifted above the level of those at or near the middle of a board. Slips are of the greatest advantage for bordered fabrics which are made in various widths from the same pattern, for the number of body repeats can be increased or reduced at pleasure by adding or removing slips. A plan for doing this was patented in 1880 by W. L. Ellis and S. A. Ellis. It consists in using two supplementary boards which are

placed 12″ to 15″ higher than the ordinary board, and both capable of lateral adjustment. Each border twine is passed through a hole in the top and bottom boards, but the body twine only passes through holes in the lower board. In case the width of such a harness has to be altered, the required number of body repeats are removed or added, and the upper board is moved in an opposite direction to the bottom border slips until the border mails fall into the same plane as the middle mails. The same effect may be produced, without the objectionable friction caused by the foregoing, if decked mails are used for the border portions of a harness, and, after adjusting the middle repeats, the border threads are drawn through the eyes that are level with the body portion.

(*c*) Comber boards consisting of longitudinal strips of 1, 2, 3, 4, and 6 holes deep are also used; they fit into end pieces and are bolted together. When such a harness has to be reduced in fineness, the requisite number of strips, with their accompanying mounting, are removed and suspended in any convenient place until again required.

(*d*) A reed is divided into sections by stretching cords, or by laying iron rods, at right angles to the dents. Pieces of notched wood are placed at intervals across the reed and firmly secured upon it. Both ends of the rods are dropped into the notches, and the harness twines are passed between the rods and dents. A harness reed differs in count from a weaving reed in proportion as the mounting threads per dent exceed the warp threads per dent. Instead of a reed, wires may be placed longitudinally and transversely in a clamping frame so as to leave interstices for the harness threads to pass through.

A board should not be broader than is absolutely necessary, or the warp controlled by couplings in the back

rows will not be lifted high enough to allow a shuttle to pass beneath them. In most cases the number of holes in one row from back to front equals the number of needles in one vertical row of the Jacquard; but it is impossible in all cases to follow this course, for some fine fabrics require as many as twenty-four holes to each row, and yet with a large number of holes in one short row the mounting threads tend to chafe and stick as they rise and fall.

If one warp thread is passed through each mail, the number of holes in a lineal inch of the comber board must equal the number of threads in one inch of the reed. Thus, assuming a reed with 80 threads per inch, and a Jacquard with 8 needles in a row, the harness will be least crossed and will last longest if the board has 10 rows, each 8 deep, on one inch; the second row to be drilled relatively to the first as in Fig. 119. If a board with more than 80 holes is used, the surplus holes should be left at regular intervals, and for preference in full rows at every place. With 100 threads per inch in a reed, and the needles in rows of 12, a board should have 100 holes per inch, or 25 rows of 12 on three inches.

When the loom cranks are on their back centres, a comber board is fixed horizontally by brackets to the loom frame, with its front edge about $\frac{1}{2}''$ behind the slay and, if the couplings pass through holes in the board, from 9″ to 12″ above the mails, but if the mounting threads pass through the board from 12″ to 16″ should be allowed. A low board prevents the mails from swinging, but may obstruct light as well as the weaver's freedom of action.

A mounting thread is used to connect the upper coupling loops with the tail cords of a Jacquard. Linen yarn is employed for this purpose, the thickness and structure of which vary greatly, and depend upon the severity of

the work to be done. From $3/60^s$ to $15/30^s$ is used for different fabrics, but 12^s, 16^s, and 20^s, in 3, 4, and 5 folds, are largely used for the ordinary run of goods. A thread containing many folds is smoother and stronger, although more expensive, than one containing few folds, but smoothness may be increased by polishing the threads before using them. From the point of view of strength, a $9/30^s$ is superior to a $4/12^s$, yet both are nearly equal in count. In the lengths of mounting thread there are also great differences, principally due to the width of loom, but also in a smaller degree to the position of the Jacquard. A narrow loom harness should be at least 4′ 6″ from a mail to the bottom of a hook, but 5′ 3″ to 5′ 6″ is to be preferred, while a loom with a reed space of 160″ requires 8′ 0″ or more from mail to hook. Excessive length, however, is as undesirable as insufficient length. At a given height, the life of a harness decreases in inverse ratio to its width. Some are worn out in less than one year, but with proper care all should last from three to upwards of six years. If the side of a Jacquard and the side of a comber board are parallel, as on 1, Fig. 117, a harness may be from 6″ to 12″ shorter than where the end of a Jacquard and the side of a comber board are parallel, as on 4, Fig. 117, because in the former the mounting threads are straight, while in the latter they are twisted and will wear rapidly.

The following methods of mounting Jacquards over looms are frequently met with:—(*a*) They are supported upon the loom framing. In that event each loom is self-contained, but requires staying from the roof or walls to avoid excessive vibration. (*b*) Jacquards are supported upon wooden or iron girders placed at right angles to the room shafts, and extending from one end of the weaving room to the other. The girders rest upon two uprights

bolted to the top rail of each loom. This plan is open to the objection that one loom, when at work, may set up a swinging motion in the harnesses of adjacent looms. (*c*) Jacquards are supported by beams suspended from the roof by long bolts. In this case the roof is subjected to vibrations which render it leaky, and then water frequently percolates into the room, to the injury of the machinery as well as the materials being manufactured. (*d*) Jacquards are supported from girders which rest in lips cast upon, or in split clamping pieces bolted to, the columns of the room. This plan is preferable to any of the foregoing, for it reduces vibration to a minimum on account of the Jacquard being free from the loom and the roof.

If wooden beams are used, supplementary appliances, such as card cradles and guide rollers, can be readily attached, and the Jacquard may be fastened in any position, but they are liable to warp and crack, and, owing to their large dimensions, to obstruct the light. I-shaped rolled-iron or steel girders are preferable. Their height from the floor varies with the height of the building in which they are erected, and also to suit the widths of the looms. The lips upon the columns are fixed to place the top of the girders from 8′ 0″ to 11′ 0″ above the floor line, 9′ 0″ being a good average. Cross girders are placed upon the longitudinal ones and should be attached by clips, for clips permit of adjustment to suit either large or small Jacquards. The latter are then either fixed to the cross girders or to stands bolted upon those girders.

A Jacquard should be capable of vertical adjustment, so that the mails may be placed on their proper level. This is usually accomplished by inserting setting-screws in the machine feet, and allowing them to abut against a solid bed.

If a machine is fixed for the cards to be suspended above the warp, as at 1, Fig. 117, where both Jacquard and comber board are shown in plan, or over the fabric, as at 2, the driving belt and wheels are not liable to injure the cards, but this course may reduce the light where light is most wanted. If the cards are suspended above one end of a loom, as in 3, 4, the harness must be twisted, and friction and wear are thereby proportionately increased. Local circumstances, however, determine the position of a machine, such as the space available for cards, light for the weaver, and the nature of the lifting tackle; but these can only be dealt with on the spot.

Before beginning to tie a harness, the exact position a machine is to occupy must be determined. Thus, if one machine only is to be used, a plummet line tied to the centre hook should hang immediately over the comber board centre, as at A, Fig. 119. If two or more machines are necessary, set them as close together as possible, with the centre of the space separating them, or the centre of the middle machine over the centre of the board.

Harness-building

Harnesses may be built at the loom or in a specially fitted room. If the work is done at the loom, a stoppage of at least one week will be necessary; but if built elsewhere, the loom need not be idle for so long a period. The following methods of building harnesses are in general use:—1. Where single mounting threads are employed to unite the couplings with the tail cords of the hooks. (*a*) At a higher level than the comber board. (*b*) At a lower level than the comber board. 2. Where a mounting thread serves instead of a top coupling loop. Single mounting

threads are then employed to unite the mails with the tail cords. 3. Where double mounting threads are employed to unite each coupling with a tail cord.

If a harness is intended for a narrow loom, and for the first-named style of tying, the mounting threads are warped to the length of that thread farthest removed from the perpendicular when in the harness, plus an allowance of 3″ to 5″ to facilitate tying. But if the harness is for a broad loom, it may be advisable to warp the threads in two lengths, the shortest for those that will be least removed from the perpendicular, and the longest for those that will slope most. A frame of warping consists of four pins bolted into a wooden or iron rail A, Fig. 115; the pin E is placed in a long slot for the purpose of adjustment, and must be fixed far enough from B to give the proper length of thread. The twines are drawn from warping bobbins held horizontally in a creel and tied upon E, from whence they are taken alternately over and under D, C, round B, and back again to E, but alternately over C and under D. This order is continued until a sufficient number of mounting threads are obtained. A lease band is then passed through the openings made by the pins C, D to hold each thread in its proper place and thus avoid entanglement. They are next cut at E, loosely bunched together, and removed from the pegs. Assuming six repeats of a straight pattern to be needed in the harness, three of the doubled threads must be tied to each neck cord in the machine at a point from 6″ to 9″ in single necks, and from 9″ to 12″ in double necks, below the hooks. But since these threads will be widely separated in the comber board, the risk of falling threads hooking into rising ones when at work must be obviated by tying a knot on each bunch from $3\frac{1}{2}$″ to 5″ below the point of connection with the neck cords. The

knots are tied to fall in a straight line across the harness as follows: Two pins are driven into a piece of wood $3\frac{1}{2}''$ to $5''$ apart, a knot is loosely tied upon those threads that form one set, and one pin is passed through their looped ends, the other through the centre of the knot. After a given number of knots have been made, they are slipped one by one from the pin and pulled tight; in that condition they are ready to be connected to the machine. This may be done before it is put into position, or after, as may seem most desirable. A less bulky and equally satisfactory bind-

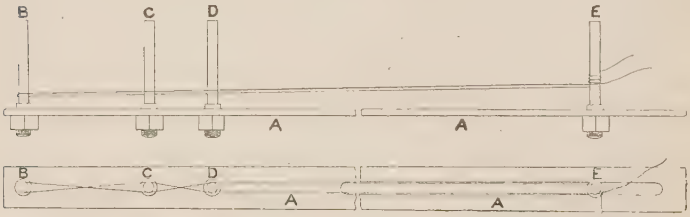


FIG. 115.

ing may be obtained by coiling a single thread round a group of mounting threads to form a band about $\frac{3}{8}''$ deep and tying the ends tightly at about $4''$ below the junction with the tail cords. Or a cross thread may be sewn into the mounting threads to form a flat neck, as at D, Fig. 90.

If the harness is to be built at a loom two building rods are employed, and each must be long enough to reach across the warp space. The rods vary from $2''$ to $6''$ in depth, and are shaped as shown in the sections in Fig. 116. The lower rod A is passed through the bottom loops of the couplings B to support them until they are tied up, and the upper rod C goes through all the top loops D. The rod C must be fixed horizontally under the comber board centre with its lower edge at such a

height that the mails F, when drawn against it, will be in the bottom shed line. The position of this line is sometimes determined by stretching a cord from the breast beam to the back rest of a loom and fixing the mail eye at from $1\frac{1}{2}''$ to $2''$ below the cord, which is approximately half the depth of a shed. For centre shedding the mails should be almost in line with the tight cord. In place of the foregoing method a flat wire may be threaded through all the mails and subsequently corded securely upon the top of the rod C, in which event the rod A is superfluous. Both rods A, C are supported upon adjustable brackets bolted on the loom ends, or in a wooden frame having two upper and two lower adjusting screws at each end. After being secured at their proper height and levelled with a spirit-level, the comber board is marked off into patterns by lead lines upon its edges, and if there are surplus holes, a pencil is drawn across them. Filling is next proceeded with. For tying above a board this consists in drawing the upper loops of the

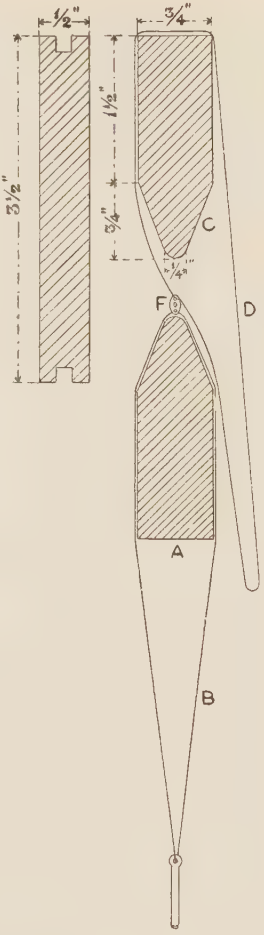


FIG. 116.

couplings D through successive holes in the comber board. Then follows the actual operation of building, or uniting the Jacquard and couplings.

If a machine is fixed for the cards to be suspended either over the warp or the fabric, all hooks in one long row are connected with couplings in one long row of the board; but if the cards are suspended over one side of a loom, the hooks in number one short row are tied to the couplings in the first short row of the board.

When facing a Jacquard cylinder, D, Fig. 117, the leading hook is number one in the back row on the left, as at B. Assuming the builder to stand in the working alley and the cylinder D to be over the warp, this hook must be connected to number one coupling in the front row on the right, as at C, No. 1. If the cylinder D is over the fabric, the leading hook B must be attached to the first coupling in the back row of holes at the left of the board, as at C, No. 2. But, as compared with the former, this will reverse the direction of any diagonal line in a pattern; still, by lacing the cards backwards, the twill will be restored to its proper direction. If the cylinder D is on the right of a loom, as at No. 3, the leading hook B must be united with the first coupling in the front row of holes at the left, as at C, No. 3; and if the cylinder D is on the left of a loom, the leading hook B must govern the first coupling in the back row on the right, as at C, No. 4.

A coupling knot is drawn to within an inch of the top, then a mounting thread is passed through the loop and its mail is pulled close against the rod C, Fig. 116; a knot is tied, and the loose end cut off. Following threads from the leading hook are tied to the first coupling in each succeeding repeat of the pattern, and the same course is

followed with the remaining hooks and mails until the harness is complete.

In Fig. 118 the knots and connections used in a harness of the foregoing description are shown; A, C are on the bottom and top loops of a coupling; B on a coupling and lingoe; D on the mounting twine and coupling; E a knot for the bunches of twine; F one for the neck cord and mounting; G one for the neck cord and hook. H shows a

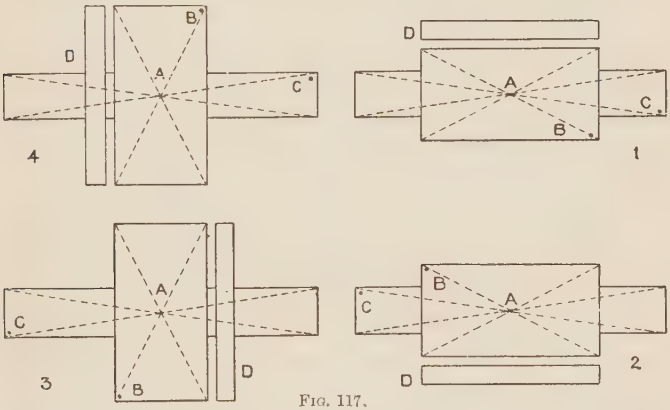


FIG. 117.

method of connecting a hook to a neck cord when it is probable one harness will have to be replaced by another: this plan provides a ready means of connecting a harness to, and disconnecting it from, the Jacquard hooks. Spring clips are also attached to neck cords to facilitate the changing of harnesses, as one may then be quickly unhooked and another hooked on.

Jacquard hooks are also specially made for this purpose, as shown at I, where a hook is bent in the usual manner at J to rest upon a rack, and again bent at K to receive a noosed neck cord L. The cord L can then be slipped off

when not further required. A similar plan is shown at E in Fig. 107.

If a harness is to be tied below the comber board, the first operation is to warp, and knot, bind, or sew the

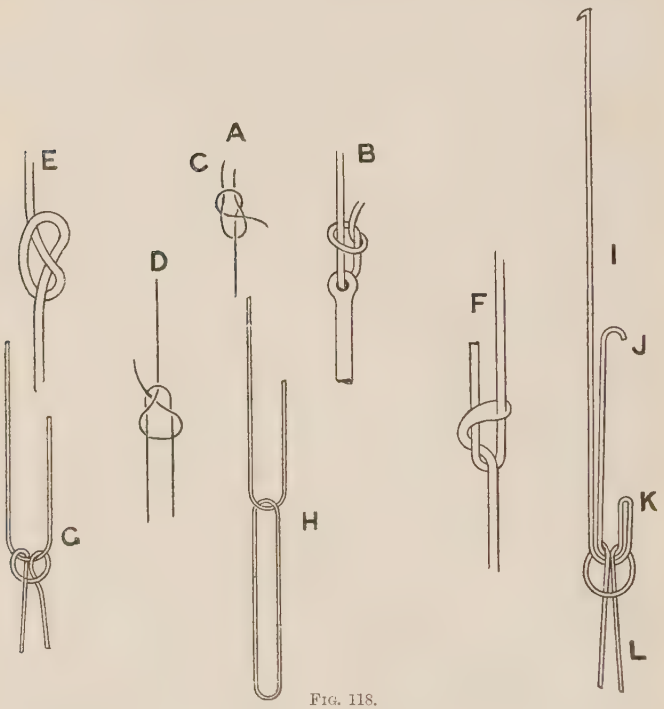


FIG. 118.

mounting threads together; they are next suspended by their loops from a rod fixed above the comber board. After dividing the board into spaces suitable for the repeats of the pattern, each twine is drawn into its proper hole in the board. The lower ends are bunched to prevent disarrangement, and the board and mounting threads are

taken to the loom, or to the building frame, where the threads are knotted in rotation to the neck cords. The comber board and levelling rods are next fixed in position. In a harness of this description there may be four or more levelling rods upon which the couplings are threaded, especially if a comber board contains many holes in one short row. Assuming one with twenty-four holes to a row to be selected, four pairs of rods may be used, or one pair adjusted four times, the back pair to be from $\frac{3}{16}''$ to $\frac{1}{4}''$ higher than the front pair, as they then assist in holding all the lifted warp threads in one line. Levelling rods, shaped as in the section on the left of Fig. 116, may be used; the grooves permit the heads of the mails to enter, and bed against the lower surface of the rod. Mounting threads from the six back rows of holes must be tied in rotation across the harness to couplings on the back pair of rods; the couplings for the following six rows of thread are on the next pair of rods, and they, with all the remaining couplings, must be similarly connected.

For fine harnesses, in which the Jacquard cylinder is over one end of a loom, it is preferable to tie below a comber board, for, when tied above, a difficulty is experienced in passing one's fingers between the threads in the last few rows of each pattern, and it becomes next to impossible to tie those threads correctly. Further, when tied below a board, the rising and falling threads are less liable to engage each other, for the knots are tied where the harness is widest. But unless the knots are from 4″ to 5″ below a board, some of them will be lifted into the holes of a board and stick there. For this reason the mails must be farther from a board when tied below than when tied above.

If a coupling consists of a lingoe, a bottom loop, and a mail, the mounting threads are warped to the required length, namely, to reach from a tail cord to a mail eye and back to a point from nine or twelve inches above the comber board. After warping they are attached to the neck cords. An open knot is next tied upon the first thread above the level of the comber board, and the end of that thread is passed down through a hole in the board; it is then threaded through the upper eye in a mail, led back again through the same hole in the board, and through the open knot. By pulling at the end of this thread the knot closes upon the return length, and finally, a second knot is tied at from six to nine inches above the board. Other threads are treated in a similar manner. In most of these harnesses the mounting threads are varnished and tied in a wet condition.

That so-called warped harnesses are in great repute with many manufacturers is partly owing to their neat appearance, and partly to the expedition with which they can be built. The system is similar to that of tying above a board in so far as marking the comber board off in sections, filling it with coupling twine, and setting up the levelling rods are concerned. But instead of warping and knotting the mounting twine as previously described, a large bobbin of thread is suspended from a skewer and placed opposite the comber board. As the thread is drawn from the bobbin it is passed through all the coupling loops that one hook is to govern, then the end is carried up and made fast to a tooth of a coarsely pitched comb, which is fitted horizontally amongst the neck cords, with its teeth in line with the points of attachment. The comb consists of stout wires driven into a wooden back, and spaced about $\frac{1}{4}''$ from centre to centre, each tooth being from 2″ to 4″ long. The

twine is then lifted between the two last coupling loops, and hooked upon a tooth adjacent to the neck cord which is to carry that thread. In a similar manner the thread between every pair of loops is taken up to the same tooth, and finally it is cut off when the starting-place is reached. These mounting threads also pass between the teeth of a similar comb fixed in the same framing, but $4\frac{1}{4}''$ below the former. The teeth of the bottom comb hold all the threads of one group close together. All the mails are drawn to the levelling rod, by pulling both ends of the thread tight, then the ends are twisted round the bunch immediately above the second comb and tied together. By this means an equivalent to a knot is obtained. The process is repeated with the remaining couplings.

On the completion of one row the bunches are taken in rotation from the comb, pulled tight to ensure evenness, and each is "knotted" to its proper neck cord.

Two mounting threads are required for every coupling, but as they are simply passed through a coupling loop the strength of a warped harness is less than twice that of a single thread harness, although double the length of material has been used. In a close harness warping has a tendency to crowd, but in medium and coarse harnesses this is of little moment. The only visible knots are coupling knots.

Dressing a Harness

Most harnesses are sized and varnished to prevent the threads from fraying and breaking. For light goods they are sometimes unvarnished, at other times dressing is only applied for 3″ to 4″ above and below the comber board. For medium goods the couplings may be sized and varnished

throughout, as are the mounting threads from the tail cords to 6″ or 9″ below them. Harnesses for heavy goods are sized and varnished from the neck cords to the lingoes, and the couplings are twisted.

Numerous dressings are employed, such as boiled linseed oil, flour paste, bees'-wax and dryers, white wax dissolved in turpentine, and heald varnish. For light goods, boiled oil or white wax is usually rubbed by hand into the harness threads, but for medium and heavy goods the oil is applied with a brush. Boiled oil provides a serviceable dressing, for it leaves the twine strong, smooth, and pliant; but it takes from a week to a fortnight to dry. For heavy goods a dressing may consist of flour, or farina, fish-glue, or bees'-wax. The following sizes and varnishes are used :—

Starch	. . .	10	parts by weight.
Glue	. . .	1	,, ,,
Water	. . .	89	,, ,,

These are boiled together and applied hot. Another consists of—

Starch	. . .	40	parts by weight.
Glue	. . .	40	,, ,,
White soap	. . .	2	,, ,,
Carbonate of potash	. .	1	,, ,,
Water	. . .	664	,, ,,

The glue is slowly dissolved in hot water, the starch stirred into the heated mixture, and other materials added. The size is then applied with a brush to the harness, to spread it evenly and remove any excess.

Good varnish such as is used by house painters may be mixed with boiled linseed oil, in the proportion of $\frac{1}{3}$ varnish to $\frac{2}{3}$ oil, and applied hot with brushes.

A dark brown varnish is made from—

Boiled linseed oil	8 parts.
Orange lead	5 „
Umber ground in oil	5 „

All the ingredients are boiled together, and constantly stirred for six hours, then used hot. This varnish will keep for months and improve by keeping.

A varnish may be prepared from—

Linseed oil	7·5 parts.
Litharge	7 „
Gum lac	9 „
Lead acetate	4 „
Spirit of turpentine	0·75 „
Umber	1 to 2 parts.

The litharge and umber are placed in a bag, dropped into the linseed oil, and gently boiled together for from three to four hours. The gum lac is separately melted, added to the oil, and all boiled for a few minutes. When cool the turpentine and lead are stirred in, and the mixture is ready for use. If couplings are to be twisted, this is done separately, immediately the dressing is completed. If they are twisted before building takes place, from 1″ to 2″ of their upper loops should be left unsized. A dressing material that gives the smoothest, most supple, and durable thread is best for all classes of work, and a coat of varnish applied to a dressed harness should give a hard smooth surface.

Defective Shedding

Jacquard shedding is defective, because a top shed forms a curved instead of a straight line, and this is due to the

mails operated by vertical mounting threads rising higher than those moved by sloping mounting threads. This can be demonstrated by assuming a harness to be 100″ wide, and when measured vertically, 96″ from a mail to a hook, 12″ from a mail to a comber board, and 12″ from a hook to the point where the threads begin to separate. The length of a vertical thread between the knot and board will then be $96 - 24 = 72$″. If two threads are attached to the same hook and one passes vertically to the centre of the comber board, the other in a sloping direction to the extreme end of the board, a space of 50″ will separate them. With the board these threads form a right-angled triangle which has a base of 50″, an altitude of 72″, and a hypothenuse of $\sqrt{72^2+50^2} = 87{\cdot}66$″. If a hook lifts 4″ the altitude becomes $72+4=76$″, and the hypothenuse becomes $\sqrt{76^2+50^2} = 90{\cdot}9$″. The difference between one hypothenuse and the other is $90{\cdot}9 - 87{\cdot}66 = 3{\cdot}24$″; therefore the inclined thread only lifts 3·24″, while the vertical one lifts 4″. This defect is greatest in wide, short harnesses; but it can be minimised by passing glass, steel, or wood rods between the long rows of neck cords, and stout wires between the short rows. Both sets are fixed in one frame, but one set at right angles to the other. The frame is placed below the neck cords to hold the rods against the mounting threads, and prevent them from opening as they are lifted by the hooks. By this means the angle becomes a fixed one, and a level top shed is obtained, but at a cost of increased wear and tear. Harnesses used under conditions similar to those assumed above often require heavier lingoes at the sides than at the centre, on account of increased friction at the comber board.

Tie-ups

Unless each tie-up contains some distinctive feature, no useful purpose will be served by giving a variety of them, for Jacquard ties, like drafts for healds, are made to suit special requirements. But in deciding upon a tie-up care should be taken to select, for a repeat of the pattern, a number of needles which can be divided oftenest without leaving a remainder, as this will enable a designer to introduce numerous small weaves. Thus: A 100 Jacquard contains 104 needles, yet 96 will give more divisions than the full number, for, 2, 3, 4, 6, 8, 12, 16, 24, 32, and 48 are all measures of 96, while from 104 only 2, 4, 8, 13, 26, and 52 are obtainable, and in all but special cases 96 needles to a repeat are preferable to 104. What applies to a small number of needles applies equally to a large number.

Straight-through Ties

A straight-through tie forms the basis of all ties and will produce most patterns and fabrics. It is only discarded in order to effect an economy in cards in one form or another, as by enabling a small Jacquard to weave large designs. In Fig. 119 a plan is given of a comber board containing an unbroken series of holes, but it is divided by imaginary lines into four sections, each equal to the number of warp threads in a pattern. Threads from number 1 hook go through number 1 hole in each section, and those from succeeding hooks go through succeeding holes until all are filled; the threads from the last hook will then be in the back hole of the last row of every pattern, as shown by the number 400. Diagonal marks, beginning at the

same part of each section and running in the same direction throughout, indicate a straight tie.

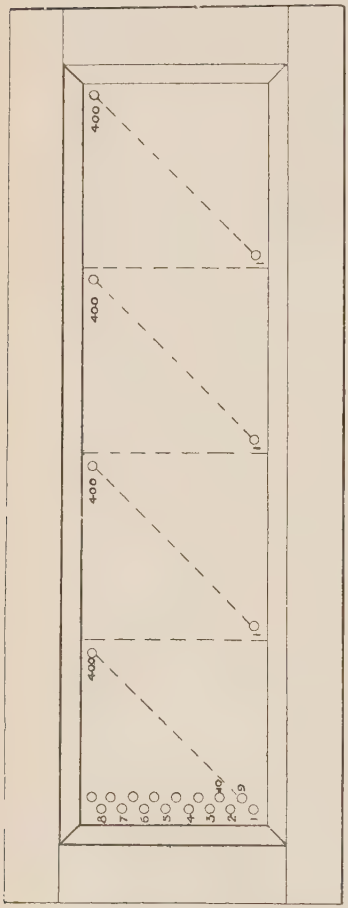


FIG. 119.

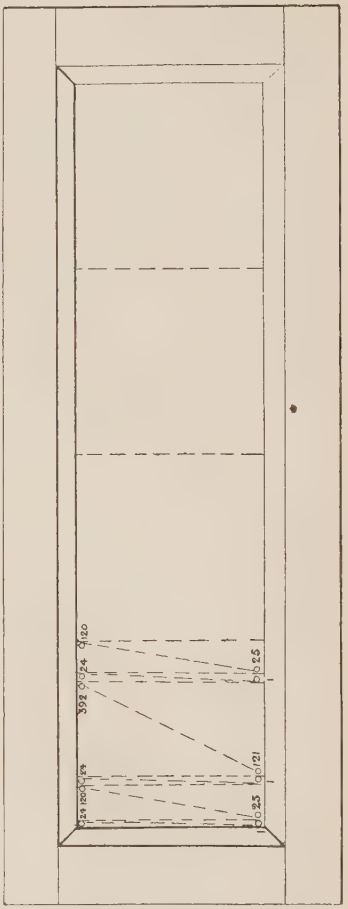


FIG. 120.

A tie may be straight in the sense that all diagonal lines shown on a plan point in the same direction, but

one section of a pattern may repeat oftener than another, as in Fig. 120, which is intended to produce longitudinal stripes of various widths and weaves. Economies are here effected by moving three threads in a pattern, namely, those numbered 1 to 24, with each needle used to weave the narrow stripes; two threads with those numbered 25 to 120, in the medium stripes; and one thread to each pattern for the wide stripe; these are numbered 121 to 392. There are thus $24+96+24+272+24+96=536$ warp threads to a pattern, but only $24+96+272=392$ needles are employed to move them.

Centred Ties

Another method of producing large effects from a small card is by centring a tie, for this doubles the width of a pattern, but the figure must necessarily possess fewer flowing lines than a straight-through tie permits of, because one half exactly corresponds with the other. Any number of repeats may be obtained, but two threads are used to each, except those governed by the first and last needles; hence to find the number of threads to a repeat, two must be deducted from twice the number of needles used, as $400\times2-2=798$. Fig. 121 is a plan of a centred tie; from 1 to 400 the tie is straight, but from 399 to 2 it is reversed, and in leasing it will be necessary to gather the threads 399 to 2 in the opposite direction to the threads 1 to 400. A harness may be leased straight if the tie is centred, as in Fig. 122, where 400 of the first half is in a back row of the board, and 399 of the last half is in the second row from the front, an empty hole being

left in one row at every point to keep the courses even

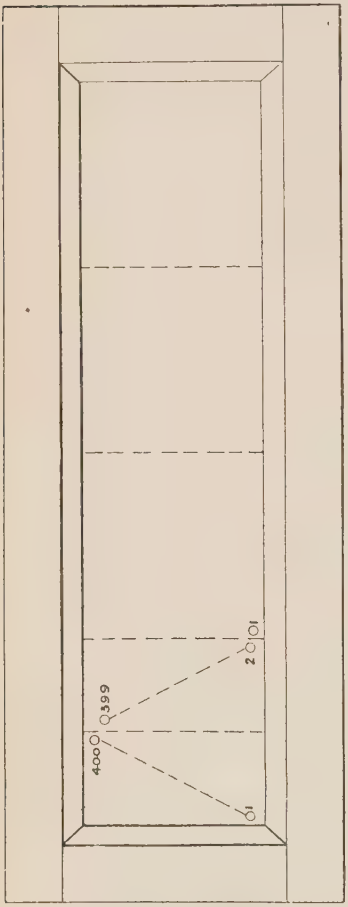


Fig. 121.

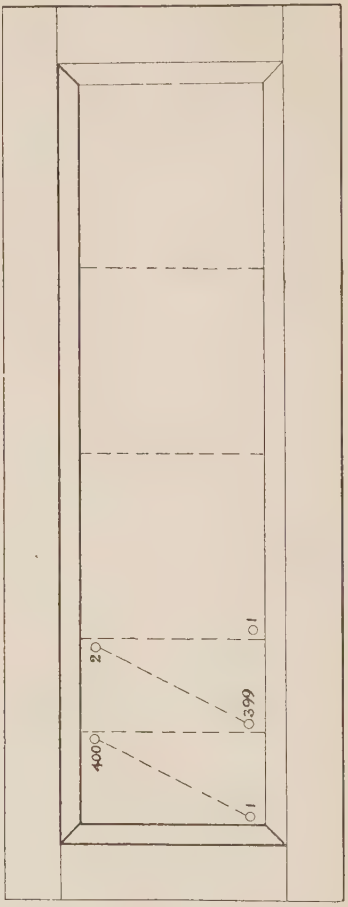


Fig. 122.

in the board and prevent two threads working as one at such places.

Mixed Ties

Some ties are partly straight-through and partly centred —straight-through in the body portion, centred in one or both borders ; others are centred at the middle only ; others again have centred borders and body, with straight-through portions between, of which it need only be said that care should be taken to prevent two odd or even threads from joining at any part—for instance, where the last body repeat joins a centred border,—otherwise defects in a fabric will be produced. By omitting the last body mail, or the first border one, this trouble may be avoided. Mixed ties are in general use where woven devices are worked in the centre of a fabric, such as a towel, a bath sheet, and a bed-cover.

Compound Ties

Compound ties are found in great variety, and may be straight, centred, or mixed. The essential feature of a compound tie consists in dividing a harness into two or more distinct sections, each to control warp of a different colour or count, or to produce a different texture. For this purpose a comber board may be divided longitudinally as well as transversely into equal or unequal parts, so that the mails in each longitudinal division may govern all the warp belonging to one section.

Fig. 123 is a plan of an equal compound tie in two sections. The Jacquard is divided equally, and consecutive needles from 1 to 200 control the couplings in section A ; and needles 201 to 400 control the couplings in section B.

If, as frequently happens, the sections are in the proportion of two couplings in A to one in B, the board must be divided to correspond, as in Fig. 124, in which the

board has twelve holes to a row, and 8 of them form section A, while the remaining 4 form section B. With a

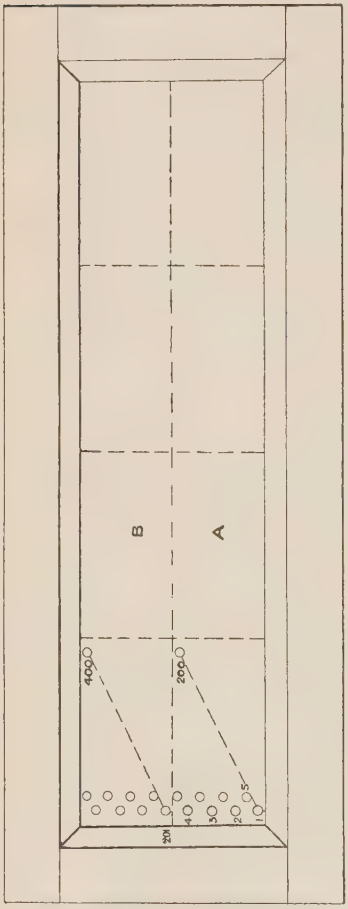


FIG. 123.

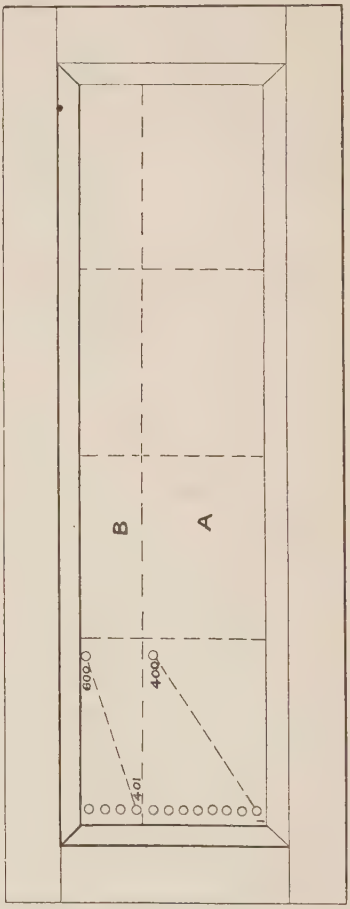


FIG. 124.

600 Jacquard, 400 needles may be used for one repeat of A, and 200 for B. Three or four sections can be formed

in a similar manner. In every case the leasing must bring the mails into their proper sequence; thus in Fig. 123 the first mail of section A must be followed by the first of B, and alternately throughout; but in Fig. 124 the first of A is followed by the first of B, then the second and third of A are taken before the second of B, the fourth and fifth of A are followed by the third of B, and so on to the end.

Compound ties of the foregoing description are adopted

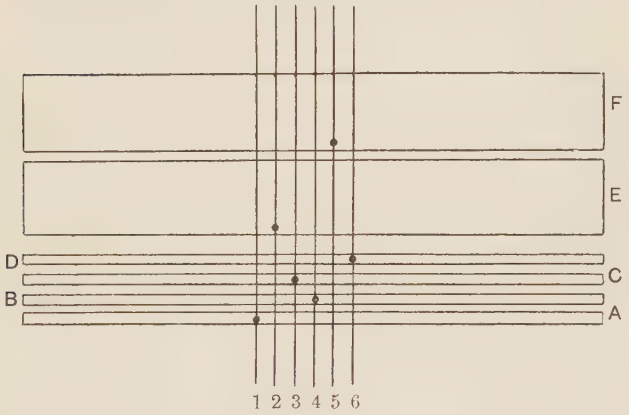


FIG. 125.

for convenience, and for reducing the cost of designing for many classes of fabrics, rather than for effecting economies in cards. Other compound ties, as compared with straight-through ties, save cards to the extent of from $\frac{1}{2}$ to $\frac{79}{80}$; they are usually built for weaving compound fabrics, which are stitched together in the loom. Fig. 125 is a plan of a mounting, commonly used in the manufacture of quilting fabrics, consisting of 4 shafts of healds, A, B, C, D, which control all the threads of one warp, and two comber boards, E, F, each containing half the remaining warp. Vertical

lines 1 to 6 are warp threads, of these 2 and 5 only belong to the back fabric. A dot denotes the position of the heald or mail eye that each thread is drawn through. Fig. 126 is a plan of the Jacquard portion of this tie; it is arranged for a 400 machine, and the numbers 1 to 8 show where the couplings governed by the first row of needles are placed. The building differs from any of the systems described in having a knot tied upon every coupling immediately above a board. Each knot is too large to pass through a hole, but does not limit the power of a Jacquard to lift the

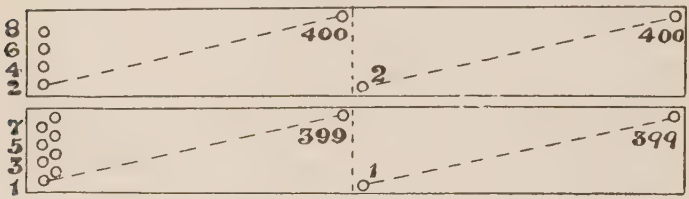


FIG. 126.

couplings. The shafts and boards are all actuated by tappets independently of the Jacquard. Thus, if the shafts A, B, Fig. 125, lift with the first upward movement of the griffe, all odd threads of the face warp will be raised, together with certain threads of the back, to form a shed for the first pick of face weft; A, B then sink, and C, D rise without movement in the Jacquard for number 2 pick of face. Thick padding weft is used for picks 3, 4, to give bulk and weight to the fabric, for both of which the shafts A, B, C, D are lifted, and the griffe remains up, but it must drop before the back pick 5 is inserted, and before it rises again the comber board E is lifted together with A, B, C, D.

It will be noticed that only one card has been employed

to place 5 picks of weft in the fabric, and 5 following picks will be driven home before number 2 card is replaced by number 3 as follows :—

For pick 6, A, B, and the Jacquard griffe lift.
„ 7, A, B, C, D, „ „
„ 8, A, B, C, D, „ „
„ 9, C, D, „ „
„ 10, the griffe descends, and A, B, C, D, and the board F lift.

By operating the boards E, F, on picks 5, 10, plain cloth will be produced with the back warp and weft, because all even back threads are on F, all odd threads on E, and the knots being unable to pass through the holes, the couplings are lifted with the boards. Of the remaining eight picks, 1, 2, 6, and 9 are used for face, and 3, 4, 7, and 8 for padding. The Jacquard stitches both fabrics together by carrying back warp over face picks, and produces a figure upon the upper fabric by pulling that fabric down in places and allowing it to bulge in others; the actual weaving being done by the healds and boards.

As compared with an ordinary harness, this plan saves $\frac{1}{1}\frac{4}{5}$ of the cards, because the Jacquard only governs $\frac{1}{3}$ of the entire warp instead of every thread. To govern every thread three Jacquards of equal size would be needed, and each machine would require a card for each pick, or $3 \times 5 = 15$ cards instead of one. But assuming an ordinary harness to govern the back warp, and healds to govern the face warp, the reduction in cards is $\frac{2}{3}$. A further reduction of half the cards may be made by using two Jacquards independently, and causing one of them to govern all odd threads of the harness, and the other all even threads. The moving boards, the knotted harness, and the healds are retained and used in the manner already described.

Thus, if both machines have 400 needles, the first will control all odd threads from 1 to 799, and the second all even threads from 2 to 800, in each repeat of the pattern. This is equal to doubling the capacity of each Jacquard and causing one card to do the work of two, as compared with the previously described special harness, or of ten as used with an ordinary harness to which healds have been added. For further particulars of this method, see "Scale Harness," p. 249.

A double-lift single-cylinder Jacquard may be used to weave fabrics of the foregoing type without the aid of lifting comber boards, but with four shafts of healds. The tail cords are disconnected and each hook operates a separate warp thread. For a fabric with four picks to a card, two face picks are of fine weft, and one filling and one back pick of coarse weft. One griffe actuates all odd hooks, the other all even hooks, and they work as follows :— One griffe ascends with either odd or even stitching threads, heald shafts one and two are lifted by tappets, and the first face pick is driven through the warps. The griffe remains stationary, but shafts one and two sink and shafts three and four rise for the second face pick. For the filling pick the griffe remains lifted and all the shafts are up. The griffe then sinks, and while the cylinder is away from the needles it immediately rises with all the hooks it is capable of controlling, namely, odd or even rows, the four shafts remain lifted, and the first back pick is driven into position. Number two card replaces number one, and a similar sequence of movements is made, but with the other griffe and hooks. This machine is used with the scale harness described on p. 249, and the cards are perforated for it in a similar manner.

Compound fabrics known as "Patent Satins" may also

be manufactured by the aid of a double-lift single-cylinder Jacquard, and without lifting comber boards, in which event each tail cord actuates a separate warp thread. The Jacquard is used in conjunction with two heald shafts. Thus, if picks 1, 2 are of coarse weft, and 3, 4 of fine weft :— For pick 1 both griffes will lift with shaft 1. For pick 2 both griffes remain up, but shaft 2 replaces shaft 1. For pick 3 both griffes sink and one immediately rises with all the hooks it controls, while shaft 2 remains lifted. For pick 4 the first griffe sinks, the second rises, and the healds change places.

The cards are cut as for ordinary Jacquards, each equals 4 picks, and the cylinder after presenting a card moves out and remains stationary until again required for the next card.

Double Equal Plain Cloth Tie

Four moving comber boards may be employed to weave compound plain textures that differ from each other in colour and are figured by passing one through the other. This system permits of any style of figure, and binds both pieces together wherever the fabrics change places. If four holes form a row, each board, Fig. 127, is about 1″ wide and from 1″ to 1½″ deep. The top loops of all the couplings are knotted, and the knots when resting upon the boards hold the mails in a straight line.

The compound Jacquard described on pp. 195-196 is fixed over the loom, and the mounting threads from all hooks that face the cylinder are connected to couplings in one pair of boards ; those from hooks that face the spring box govern all couplings in the other pair. A 400 needle machine contains 16 rows of hooks ; rows 1 to 8 face the cylinder, and 9 to 16 the heel rack. Fig. 128 shows how

these hooks are attached to the couplings for a straight-through tie ; the numbers 1 to 16 represent warp threads. If white warp is drawn through the mails on boards 1, 2, by lifting 1, only odd threads of white will rise, and board 2 will lift only even threads ; boards 3, 4 respectively move

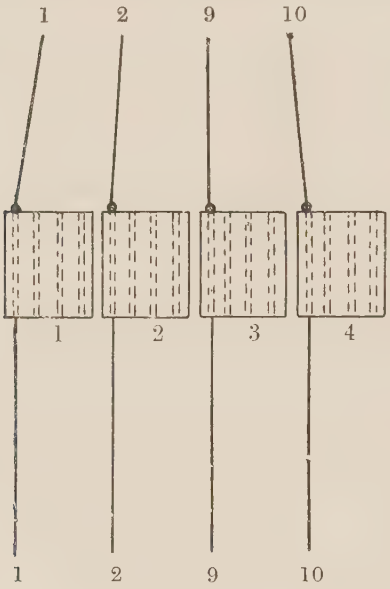


Fig. 127.

odd and even threads of the other colour, say blue. Hence without using a Jacquard two perfect plain fabrics can be woven—one blue, the other white. A Jacquard merely lifts blue warp above white weft where blue is to show on the upper surface, and white warp over blue weft where white is required on the upper surface.

As compared with two separate Jacquards and an

ordinary harness, each to weave one colour, the foregoing method saves $\frac{3}{4}$ of the cards ; for in one case two cards are needed for one pick, in the other one card answers for two picks. Thus, while the first card faces the needles, the blue griffe and board 1 lift to provide for a pick of white weft. The same card presses the needles back while the white griffe and board 3 form a shed for blue weft. Card 2 is turned into position, and first the blue griffe and board 2, then the white griffe and board 4 rise for white and blue

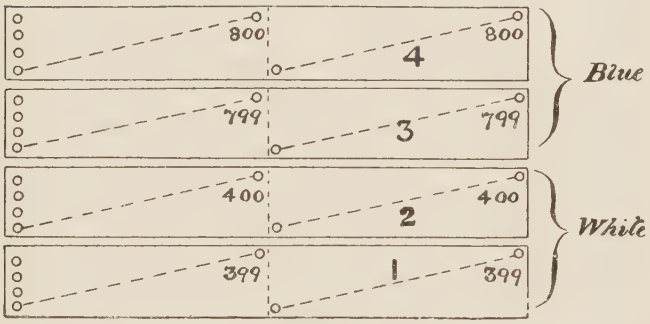


Fig. 128.

wefts respectively. With the mounting threads 1, 2, Fig. 127, connected to number 1 hook, and 9, 10 to number 9 hook, one card may be made to do the work of 16, as compared with two Jacquards operating ordinary harnesses. Thus, if the cylinder is stationary for four picks, and the blue griffe rises, the boards 1, 2 may rise and fall in rotation for two white picks, the blue griffe then descends, the white one ascends, and the boards, 3, 4 are operated for two blue picks. Card 2 replaces card 1, and the same order of lifting is followed. Therefore, since each needle governs 4 adjacent warp threads, and each card equals 4

picks, this plan has $4 \times 4 = 16$ times the capacity of an ordinary Jacquard and harness.

Split or Scale Harness

Harnesses known as "Split," as "Shaft Monture," and "Bannister" are used to weave wide patterns in fine reeds, and with small Jacquards. Some are capable of doubling, others of trebling, and others again of quadrupling the width of a design. A double scale harness may have a comber board, C, Fig. 129, fixed about 12″ above the warp, and couplings with top loops 16″ long drawn into it, if all are previously knotted 8″ above the mails at A. A strip of wood or metal, B, $\frac{1}{8}$″ thick by $1\frac{1}{2}$″ deep, is then rounded along both edges, and pushed between the loops of all couplings in one row of the board, immediately below the knots, consequently the number of shafts employed equals the number of holes in one full row of the board. Two consecutive couplings in each repeat of the tie are united to one mounting thread at D, but they can be lifted separately by the shafts in any desired order. Let it be assumed that 16 holes form one short row, then the couplings 1, 2 are tied, or warped, upon the neck cord of number 1 hook; the couplings 3, 4 to number 2 hook, etc., or the couplings 1, 3, 2, 4 may be respectively tied to hooks 1, 2; this is done to enable a Jacquard to lift plain cloth sheds without the aid of shafts; but since the couplings 1, 2, 3, 4 form parts of different longitudinal rows in the harness, they are threaded upon four separate shafts B, which may each be moved as required by extra hooks in the machine, and by cords E. Three or four adjacent couplings may be connected to one hook and treated in a similar manner.

If the cards are suspended over the warp, extra hooks

should be provided near both ends of the cylinder, so that the cords E may pass from them in straight lines through

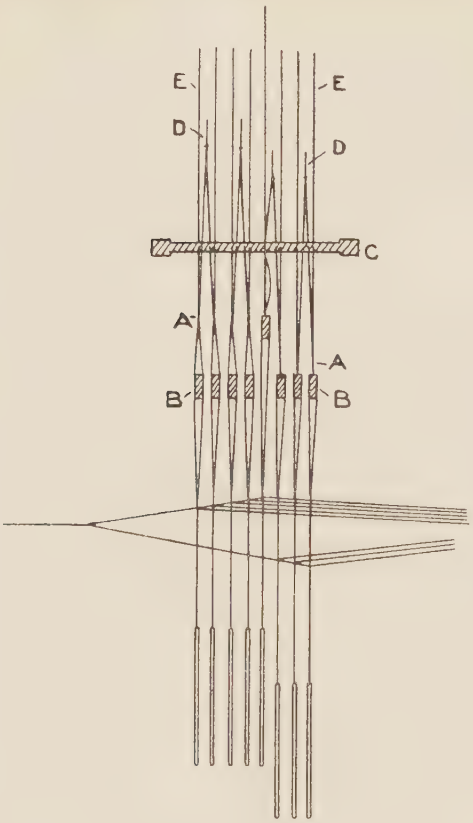


FIG. 129.

the comber board C to opposite ends of the shafts B, for this arrangement throws equal weight upon each end of the griffe. The cards are only perforated to weave the

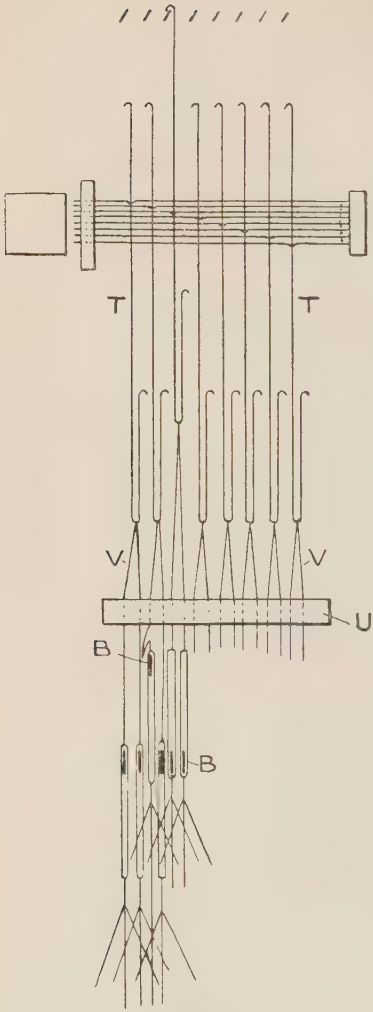


FIG. 130.

figure, therefore the shafts must lift some of the warp left down by the Jacquard in order to bind the ground portions of the fabric. One card is required for each pick.

The advantages of this harness are, that in addition to increasing the size of a pattern, different ground weaves can be obtained with the same figure, provided the hooks and needles used to actuate the shafts B are so placed that short cards may work outside the figuring cards. Less cost is incurred in designing, because the figure only requires attention. But since the warp threads are moved in pairs, in sets of three, or sets of four, a figure is slightly defective in outline.

From 8 to 24 shafts may be manipulated by attaching two neck cords V, Fig. 130, to each figuring hook T, and passing them separately through

contiguous rows of holes in a bottom board U, which is fixed 2″ to 3″ below the hooks. This board has two rows of holes for one row of hooks in the Jacquard. Each neck cord is knotted about 5″ below U, and a short shaft B is passed through each line of loops thus formed. The shafts work in the least crowded parts of the harness, and do not interfere with the weaver's freedom of action.

Another double scale harness, which has been used in the manufacture of certain kinds of cotton brocades for many years, also effects a saving of half the cards. If two separate machines are used, one governs all the odd couplings, the other all the even ones; but a double lift, single cylinder, or a double lift, double cylinder machine, with the neck cords disconnected, answers the purpose admirably. Couplings are operated by each separate neck cord in the usual manner; then, if a loom be run without cards, each griffe will cause alternate couplings to be moved, and weave plain cloth. One griffe of a 400 machine will therefore control all the odd warp threads from 1 to 799 in every repeat, and the other all even threads from 2 to 800. Any type of figure in which two adjoining threads are not required to lift simultaneously can be woven. But a warp float must be woven face down, a weft float face up.

In preparing a design for this harness the pattern will cover 800 vertical spaces on the ruled paper, and after outlining the figure in pencil, the lead lines are painted over with single dots arranged in plain order, or "on the tab." In perforating the cards two spaces on the design paper are treated as one, for one of the two will invariably be blank, hence a plain weave on the design paper requires consecutive holes cutting in any row of a card.

The Pressure Harness

A pressure harness is one in which a Jacquard is combined with healds to move the same warp threads. The figuring harness is of the usual type, but must be placed farther from the cloth fell than for ordinary work. As a rule, a space is left between the back shaft and the comber board of 7″ for cotton, and 10″ for linen warps. From two to twelve adjacent threads are governed by each hook, but they must be drawn through separate mails, or through separate eyes in a decked mail, in order to prevent them from twisting.

A set of heald shafts, equal in number to the threads in one repeat of the binding weave, are suspended as near the cloth fell as possible, and may be furnished with eyes from $2\frac{1}{4}$″ to 3″ deep, or healds in which the clasps fall in two lines may be substituted. In that event every thread is drawn above one clasp and under another, as at No. 2, Fig. 3. Or, again, single clasps, as at No. 1, Fig. 3, may be employed with double the number of shafts. For the latter, one loop of each heald is longer than the other by the depth of a shed. One set of the short loops are placed at the top, the other set below, and a warp thread passes over one and under the other. These shafts occupy more space in the loom, but in shedding they have only two positions, whereas other pressure healds have three positions. The warp, which has passed in groups of from 2 to 12 threads through the mails, is drawn singly and straight through the healds.

The Jacquard must be capable of lifting the warp without obstruction from the healds, and of leaving it lifted for several picks, during which time one shaft must sink and one rise for every pick in order to bind

both ground and figure. A sinking shaft pulls down one lifted thread from each repeat of the figure binding weave, and a rising shaft lifts one thread from each repeat of those left down by the Jacquard. If the rising and falling of these shafts is suitably arranged, a weft face weave will be formed throughout for ground, and a warp face weave for figure.

The saving effected by this harness is very great; for example, a 600 machine with 4 threads to a mail and 4 picks to a card gives a pattern that repeats on $600 \times 4 = 2400$ threads. This number of threads if moved by a single harness would require four 600 machines, and therefore 4 cards to a pick, in place of 1 card to 4 picks, or altogether $4 \times 4 = 16$ times as many cards as a pressure harness.

The smallest possible sheds and shuttles are employed; nevertheless great strain is put upon the warp; but, on the other hand, this harness is firmer and better adapted for very fine fabrics than the twilling machines which have been introduced to replace it. All twilling machines cause the ground weave to be centred where the harness is centred; but a pressure harness gives a perfect texture with any style of Jacquard harness. Curved lines produced by these harnesses are necessarily more irregular than those which result from placing the warp threads under separate control; and in proportion to the coarseness of the reed used, the figures have a stepped outline.

Pressure healds may be moved by a Jacquard, by tappets, or by dobbies. When the former is employed, one neck cord is tied to two hooks and passed under a grooved pulley A, Fig. 131. From a hook attached to A, a heald shaft is suspended by cords that descend to an upper shaft. A shaft can be placed in three positions:

first, if both hooks that control it are down some of the warp lifted by the harness will be held down by the shaft; second, if only one hook is lifted, a shaft will be put out of action, for its eyes permit the warp to be lifted by the

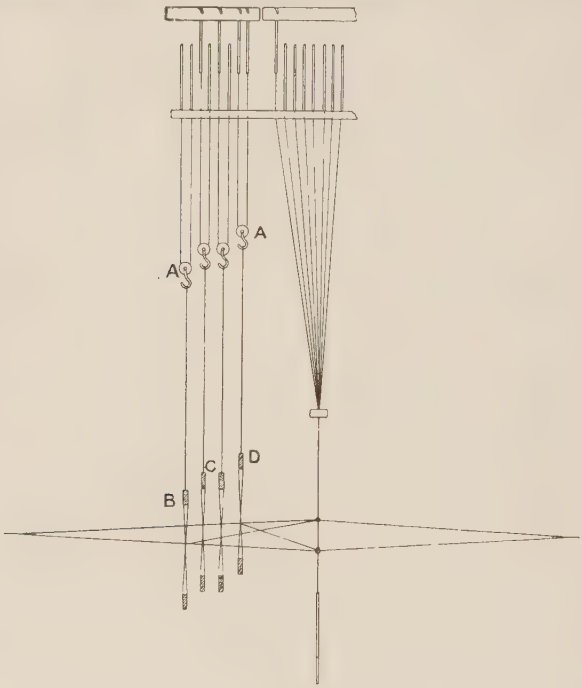


FIG. 131.

Jacquard; and third, if both hooks are lifted, some of the warp left down by the harnesss will be lifted by a shaft. But this system only lends itself to the production of unequal fabrics, in which the warp threads exceed those of the weft in the proportions of 2, 3, 4, 5, or more to 1. When both healds and mails are operated by the same

griffe there is an unequal strain upon the latter, and it cannot be left stationary for more than one pick, without leaving the healds stationary also. The warp is not lifted at the healds so high as at the mails, for if a mail is 20″ from the cloth fell, and a heald is only 10″ away, a lift of 5″ at the mails must be reduced to a lift of 20 : 10 : : 5 : 2·5″ at the heald. This actually occurs in the plan illustrated in Fig. 131. If the healds are suitably moved by tappets or dobbies, the Jacquard can remain lifted for any number of picks, and the shafts may move pick by pick to bind both ground and figure.

Gauze Weaving

Although designing and fabric structure are outside the limits of the present treatise, it will be necessary to describe how one portion of the warp threads may be twisted partly, or wholly, round other warp threads. Most tappets, dobbies, and Jacquards are employed for this purpose, but closed shedding requires fewer additions than open shedding. Special easers, and healds, reeds, or needles are needed to cross the warp. Healds are in most extensive use for general work, but the two last named possess advantages where the scheme of lifting and twisting is limited. Provision is made for lifting every twisting thread from two points, so that an open or a cross shed may be formed at pleasure, and if healds are employed, the ordinary type lift an open shed, but a heald and a half heald combined form a cross shed.

Bottom Douping with Shafts

The accompanying Figs. 132, 133, and 134 show how this effect is produced. Fig. 132 is a draft and lifting plan

for a simple gauze; the thick, short lines at A indicate that two threads pass through one dent of the reed B. The horizontal lines 1, 2 are two heald shafts, the former containing even, the latter odd, threads of warp; S, D are respectively the standard and doup, both of which are better seen in Figs. 133 and 134. A standard S is an ordinary shaft of twine or wire healds into which half healds D, also of twine or wire, have been attached either by passing the doups over and through the eyes of S, or by

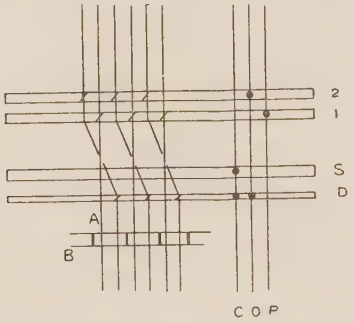


FIG. 132.

simply pushing them through those eyes. In the latter event, however, the doups are liable to fall out of position when the warp breaks. After the warp has been drawn alternately into shafts 1, 2, every odd thread is crossed under an adjacent even one, and passed through a loop of the half heald. It is the office of shaft 1 to prevent the straight threads from rising with those that cross, and for simple gauze this shaft may be dispensed with, if a rod is passed above the straight and beneath the crossing threads and then fixed securely in position.

Dots on the vertical lines O, C, P, Fig. 132, represent the order of lifting the shafts: O is an open shed obtained by

lifting D and 2, as seen in end elevation, in Fig. 133 ; C is a cross shed made by lifting D and S, as shown in Fig. 134,

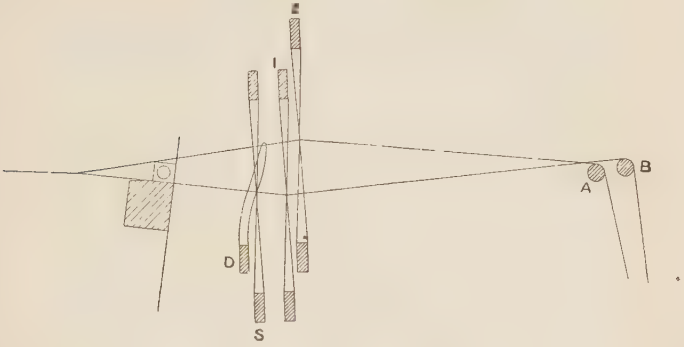


FIG. 133.

and when necessary a plain shed P can be formed by lifting 1.

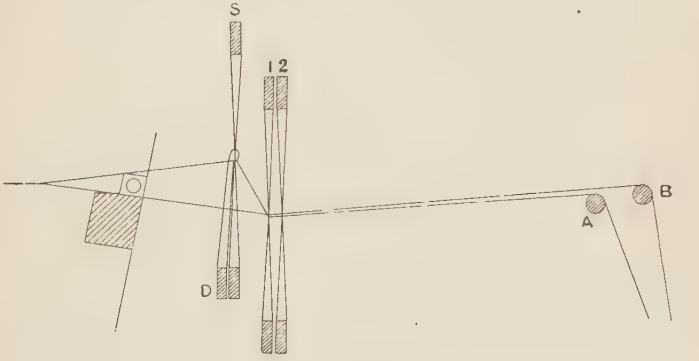


FIG. 134.

In the plan, Fig. 132, one thread crosses one, but any number of threads may cross any other number, provided all are in the same dent in a reed.

Twisting one set of threads round another set and lifting the same threads every pick are distinguishing features of gauze. For gauze weaving the threads on shaft 1 are never lifted above the weft, but as the crossing threads pass beneath them, to the right and left alternately, the

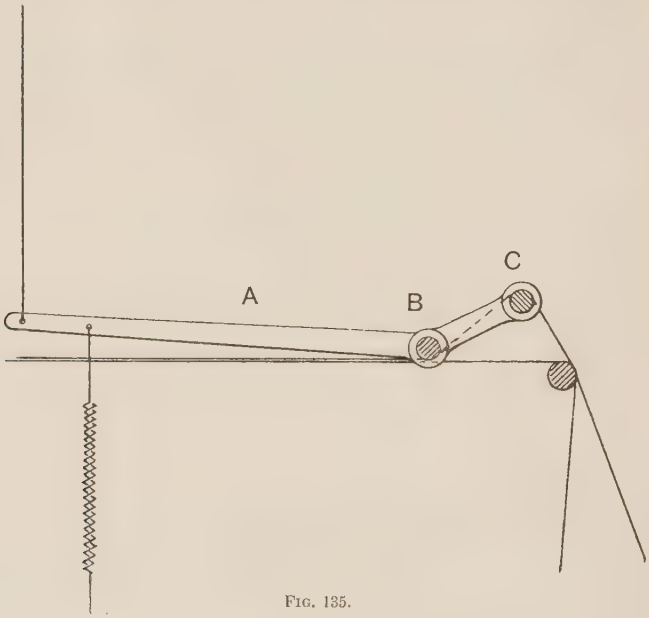


Fig. 135.

straight threads are securely bound into the fabric. Threads lifted for a cross shed would be subjected to greater strain than when lifted for an open one, unless something was added to regulate the tension. This is usually provided for by passing the stationary threads over a fixed bar B, Fig. 133, and the crossing threads over a bar A, that moves to ease those threads whenever a cross shed is opened.

Movement may be given to an easer by a dobby or a tappet, the latter being preferable on account of the timing, if the necessary mechanism is available. An illustration of each method is given in Figs. 135, 136. Fig. 135 shows a lever A, from which a cord is led to a dobby; A is fulcrumed at B, and at its extremity a rod C crosses the loom to support all the twisting threads. An upward movement of the cord lifts A, depresses C, and slackens the threads. In Fig. 136 the cord descends to a tappet treadle, and the

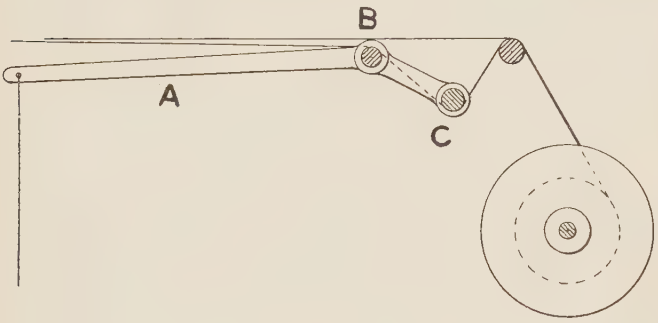


FIG. 136.

rod C is below the straight threads, hence easing is accomplished by depressing A to lift C. Instead of a bar C a shaft of ordinary healds may be employed to ease. In that case the healds occupy the position usually occupied by an easing bar, and the crossing threads are drawn through the eyes. If the easing mechanism lifts this shaft, the eyes must be placed in a lower plane than that which contains the straight threads, as at C, Fig. 136. But if the mechanism sinks the shaft, the eyes must be at a higher level than the straight threads, as at C, Fig. 135.

It is stated on p. 99 that open and semi-open sheds are not so well adapted for gauze weaving as closed sheds.

Still, any double lift shedding motion can be used provided suitable mechanism is added to lift the standing threads and sink the crossing threads to the centre of a shed, and thus permit one set of threads to cross those of the other set.

In weaving simple gauze one thread from each dent of the reed is lifted to the top shed level every pick, the others are lowered upon the race board, and between two movements of the shuttle, one set of threads must be twisted half round those of the other set. If an open shed dobby is employed to weave such a fabric, either some outside contrivance must be resorted to, or some modification be made in the construction of the dobby, for the latter is incapable of lifting and lowering a shaft on one and the same pick, without which the separated threads could never cross. The parts so added are known as shakers. Their function is to lift the standing threads from the bottom shed line to a point above that where the rising and falling threads pass each other, hold them in a state of comparative rest until the crossing has been effected, and return them in time for the following pick.

The half heald must simultaneously be lowered by the dobby to a point slightly beneath the mid position and return to the top. While the above is taking place, the standard S and the back shaft 2, Figs. 133, 134, make through movements and reverse the crossing. A shaker may consist of winged cams mounted upon the bottom shaft to lift and return the lower line of warp before the shuttle begins to move, or levers may be rocked from the connecting arms of the driving cranks, as in Fig. 137, where a bar A is held parallel with the heald shafts by brackets, and carries three arms, two of which are secured upon A at equal distances from the ends of the heald shafts, and one is seen at B. The arms B are connected by cords

to those shafts only that contain the standing threads. The third arm C is united by a link D to one of the connecting arms of the driving crank. As the latter rotates, a vibrating motion is conveyed through D to the bar A and through the arms B to the standing shafts. This movement must be sufficient to permit of crossing.

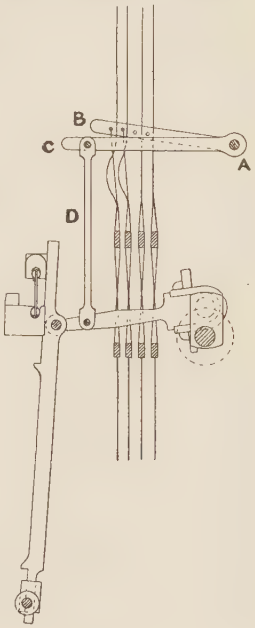


FIG. 137.

It is by far the best plan to compass the necessary movements by the addition of suitable attachments to the dobby, for, with cams and levers rocked by the loom cranks, the standing threads are lifted every pick whether or not the pattern requires such lifting. A dobby should act only when the crossing threads are to be moved to the opposite side of the standing threads.

A dobby shaker is shown in Fig. 71, but like the preceding it acts every pick whether the threads are to change places or remain unchanged. It consists in mounting a bowl 7 upon the swing lever B, and causing that bowl, both in its descent and ascent, to rock a lever 4. This lever is centred at 5 and carries a bowl 6, which impinges upon an arm 1. Two such arms are fulcrumed upon the framing at 2, and support a bar 3, having a series of holes drilled through it to permit of pegs being attached where required. As the bowl 7 passes and repasses the shoulder 8, the bowl 6 descends with the

arms 1 ; the pegs in 3 thrust down those jack levers G that operate the standing threads, and shake the heald shafts. A helical spring 9 lifts the arm 1 and the bar 3, immediately 7 has passed off the shoulder 8.

The Stafford dobby is of the Hattersley type, but

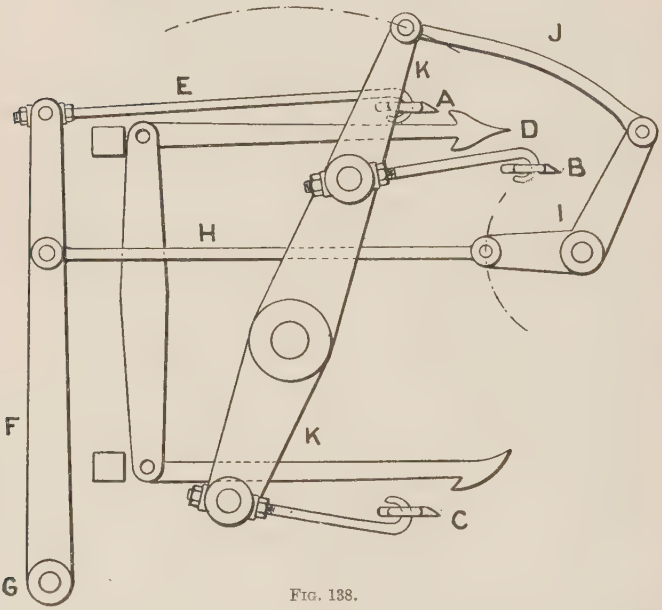


FIG. 138.

designed to permit of attachment to the loom end instead of the loom top, and to push instead of to pull the hooks. When used for leno weaving it has a draw knife A, in addition to the usual draw knives B, C, Fig. 138. A is mounted slightly above the upper line of hooks D. Four of these hooks are double-headed, and are actuated by a long peg when they are to be drawn by the middle draw knife B. But if no peg is used the hook D will be lifted into contact with A.

When a heald, governed by a double-headed hook, is to remain in the bottom shed line, a short peg in a lag will place that hook out of reach of both the knives A, B.

The knife A is moved through a little more than half the traverse of the knives B, C, and at twice the speed, in the following manner: A is attached by a link E to a lever F fulcrumed at G. A second link H connects F to one arm of a cranked lever I, and from the other arm of I, a link J passes to the three-armed lifting lever K, which is lengthened upwards for the purpose. The draw knife A makes an outward and an inward movement for every shed formed. Thus, as K is rocked to and fro by the usual vibrating rod, the lower arm of I is moved above and below its centre, and gives a half lift and return movement to those healds that govern the standing threads.

Two of the jacks are connected by straps, to a doup heald, both of which act in opposite directions, so that one will lower the doup to about the mid position of the shed, and the other will carry it back again to the top. By the combined movements of the standing thread shaft and the doup, both crossing and standing threads are brought into positions which permit the jacks that operate them to effect a crossing of the threads, on the completion of which the doup returns to the top and the standing shaft to the bottom shed.

Coarse textures, known as sponge cleaning-cloths, are manufactured by the aid of two needle bars A, B, Fig. 139; into each bar a series of needles C, D are fixed at the rate of 5 to 10 per inch, and they present two eyes to every dent in a reed. The shaft A is placed above the warp with the eyes of C at the bottom; but B is placed below with the eyes of D uppermost, and a warp thread is drawn through each eye. When the warp forms one line, the eyes

of shaft A are midway between those of shaft B, hence, by sinking A and raising B, the warp will form two lines to receive a shuttle. A, B then recede until the eyes of C, D have separated the warp about $\frac{3}{8}''$. At this instant a lever actuated by a face cam gives a sufficient lateral movement to B, to cause the threads in B to cross those in A. The next vertical movement again forms a shed; therefore if the first was open, the second will be crossed.

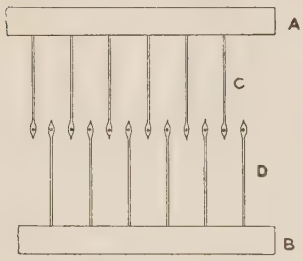


FIG. 139.

In addition to the vertical movement of A, and the combined lateral and vertical movements of B, these bars must be capable of weaving a plain texture for the heading. For this purpose they are operated by a lever and an anti-friction bowl; the latter runs in a double-grooved tappet. Both grooves are connected by a switch, and the opening or closing of this determines whether the bowl shall run in the plain or the leno groove. A change can be instantly made in the position of the switch, for it is governed by a chain composed of deep and shallow links, or by cards, or lags. The altered direction given to the bowl causes the needle bars A, B to form plain sheds alternately. One or other of the above-named selecting chains also actuates the taking-up motion, so that it may be equally adapted for plain and leno weaving, and for making fringes.

A second method of weaving heavy fabrics of the sponge cloth variety, and also applicable to a number of other fabrics, has been introduced under the name of the "heavy fabric loom."

In this loom the threads forming the warp are divided

into two parts; one half is wound upon a beam A, Fig. 140, suitably placed near the floor, the other is contained in a series of carriages in a similar manner to the method employed in weaving lace. The ends from the beam are carried upward and are passed singly through eyes on a flat bar C, which performs the functions of a harness in that it is capable of moving the threads in a lateral direction. The carriage threads are wound on brass bobbins D, and may contain upwards of 200 yards, the length being controlled by the fineness of the yarn and the pitch of the combs E and E_1. The pitch of these combs also determines the closeness of the warp threads.

The shed for the weft is formed by the carriages moving forward from one comb, E, into another, E_1, which naturally carries this series of threads, say, to the right of the beam threads. Whilst in this position the harness bar is moved so that on the return journey the carriage threads pass on the left-hand side of the beam threads, after which the beam threads are moved back into the first position.

When this double movement has been made the carriage threads have passed completely round the beam threads, producing the equivalent of a full cross leno, as shown at J. After this the weft F is inserted by means of a vertical tube G, through which the weft passes from a large upright bobbin or spool H, resting on the floor. Movement is given to the tube by a face cam situated at the side of the loom. A number of pieces can be woven in the same loom, each piece having its own weft tube, and owing to the large supply of weft, the stoppages for weft replenishing are reduced very considerably. The weft is beaten up by an open-ended reed or comb having a vertical movement. The full cross leno structure produces a fabric of considerable firmness, considering the number of warp threads per inch.

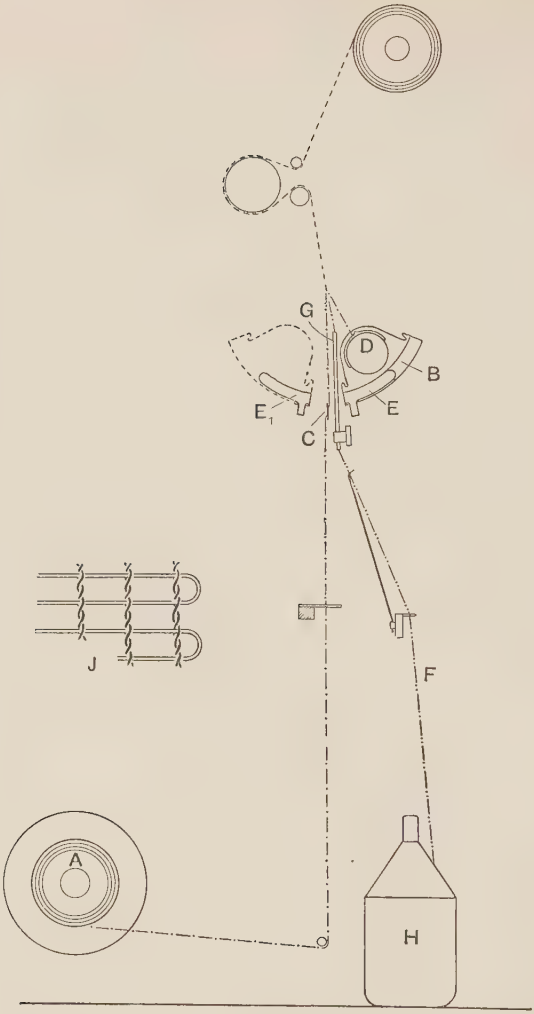


FIG. 140.

Another plan is to effect a crossing by the aid of a specially constructed reed, which is made to rise and fall by the action of a cam. This reed has a half dent A, Fig. 141, placed between the ordinary dents B, and provided with an eye near the top for a crossing thread 1 to pass through. The straight threads 2 are drawn through heald eyes, or through mails in a Jacquard harness, and are then taken between the full dents B of the gauze reed; finally, one straight and one crossing thread go into a dent of an ordinary reed.

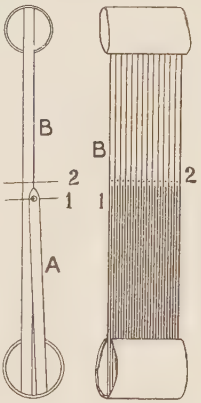


FIG. 141.

The warp threads 2 pass between the dents of a "tug" reed placed between the gauze reed and the harness; a slight lateral movement is given to this reed first to the right and then to the left; after each of such movements the gauze reed rises and thus its threads are raised alternately to the left and the right of the threads 2, forming a plain gauze texture. This device is commonly used in making Madras muslin textures.

TOP DOUPING WITH SHAFTS

A top doup differs from a bottom one in having the half heald shaft D, Fig. 142, turned to the top. Cords from D are also made fast to two pendent spiral springs, which enable the shaft to give to any unusual strain, and thus prevent breakages; otherwise, with closed shedding, D neither rises nor falls. The crossing threads 3 pass over instead of under the straight ones 4, and the healds are operated as follows:—for an open shed O, Fig. 143, the

standard S and heald 1 are lifted. For a cross shed C, the healds 1, 2 are lifted, and the easer A, Fig. 142, is moved to slacken the crossing threads. For a plain shed P standard and doup and heald 2 are lifted. It will be observed that

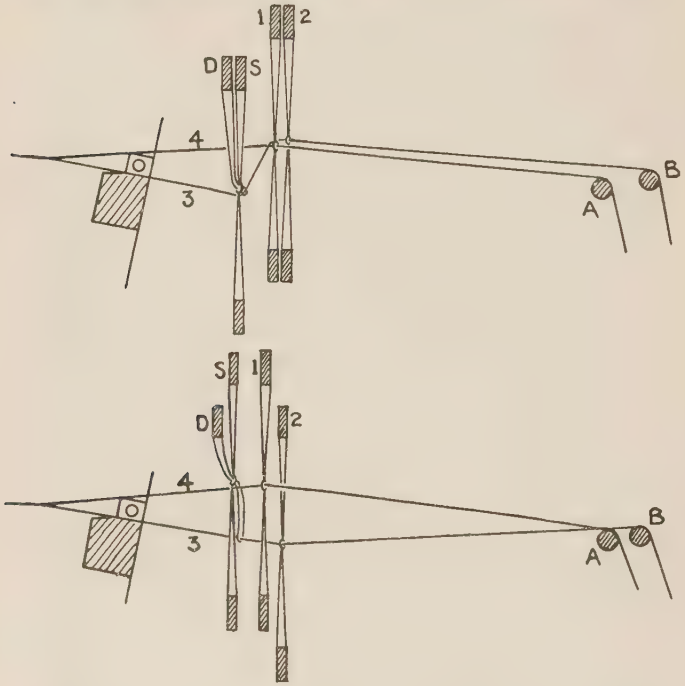


FIG. 142.

the crossing threads lifted by shaft 1 are always down where the shuttle traverses the warp, and the straight threads are up every pick. If an open shedding motion is used to actuate the healds, a shaker, Figs. 71, 137, 138, must be employed to lift the standard and doup. Shaft 2 must also be actuated by two hooks, each of which will

lift it for one pick and lower it for the next. By this means shaft 2 will sink to the middle and rise to the top every pick.

Gauze Harnesses

Special Jacquard harnesses are built to weave gauze fabrics with both bottom and top doups; still gauze can be woven with an ordinary harness if a doup and standard

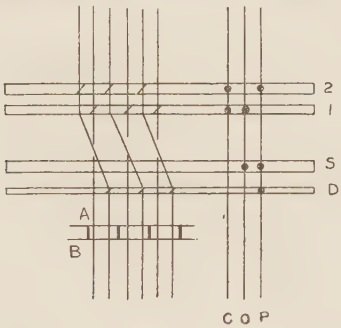


Fig. 143.

are placed in front of it, and if the crossing threads pass over an easing bar, Fig. 135, which moves to slacken them whenever the doup and standard rise together. This bar may be operated by spare hooks in the Jacquard.

For a bottom doup, with two ends in a dent, every crossing thread, after passing through a figuring mail, is taken under its fellow and drawn through a separate loop in the doup; then, for alternate picks, the standard and doup rise together and lift half the warp, say all odd threads. At the same time some even threads are lifted by the Jacquard griffe to form figure, for wherever both odd and even threads are lifted in any dent, no douping can take place, because there is nothing to cross round; but where even threads are down, the odd ones are crossed

round them. On intervening picks the half heald is lifted to put the doup out of action, and where gauze is wanted the crossing threads are lifted by the figuring harness; but to form figure odd and even threads rise together. For plain cloth only even threads rise.

A harness of this kind can be used to weave many gauze fabrics; but it is limited in the sense that only one pick can be inserted into the gauze portion of a shed if in other places plain cloth is made.

If two or more picks are put into one gauze shed and combined in any way with plain cloth, a special gauze harness is required. These are built in various ways; generally there are three distinct sections, and three separate comber boards. Thus :—

If an ordinary 600 single-lift Jacquard is fixed for the cards to be suspended over one end of a loom, and if the reed has four threads through each dent, two crossing two, the hooks must be divided into six parts, and one-sixth used for easers, four-sixths for figuring, and one-sixth for douping. For example, let 576 hooks equal one repeat of the pattern, then 8 short rows from the back of the Jacquard must be set apart for easers, 32 following rows for figure, and the next 8 rows for doups $= 96 + 384 + 96 = 576$. In the event of cards being suspended over the warp, the first two long rows of hooks will be taken for easers, the eight middle rows for figure, and the last two rows for doups. With 576 hooks to one repeat, 48 rows will be required, for $48 \times 2 = 96$, and $48 \times 8 = 384$, and $48 \times 2 = 96$. Or, $96 + 384 + 96 = 576$ hooks.

Jacquards are specially constructed for gauze weaving; of these W. and H. A. Fielding, in 1890, patented one containing 12 griffe bars, 10 of which are fastened together, the remaining pair being detached. Both sets are connected

to one lifting lever, but one is fixed nearer to the lever

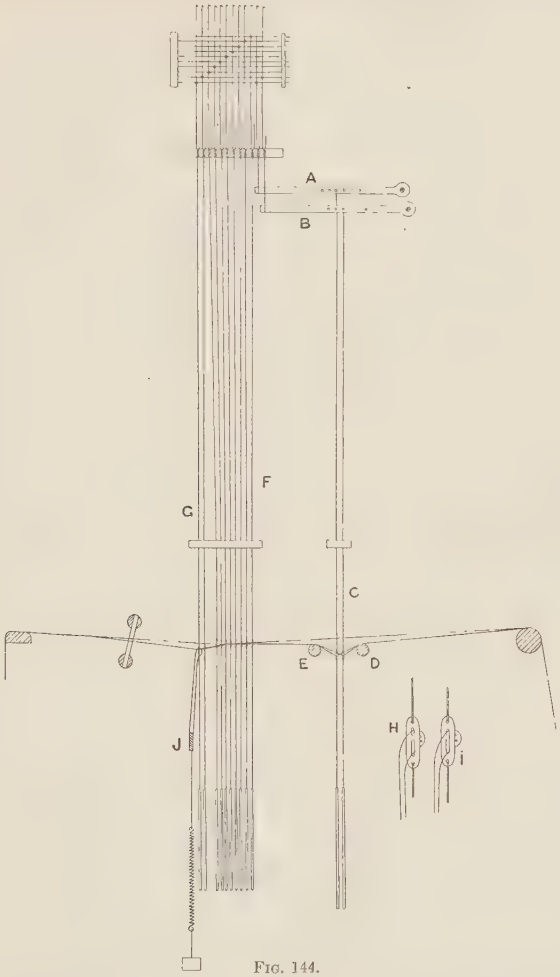


FIG. 144.

fulcrum than the other, so that the easer griffe may have

a shorter traverse than the main one, and be capable of adjustment. These makers move the doup and easing hooks by one set of needles, as in Fig. 144. This plan has the advantage of making it difficult to lift a doup hook without lifting its corresponding easing hook, and reduces the cost of cards to the extent of rendering a 500 card capable of actuating 600 hooks. In building an easing harness the neck cords may be attached alternately to levers in two lines as at A, B, Fig. 144, one approximately $4\frac{1}{2}''$ above the other. Mounting threads from the levers are then connected to the couplings C, and the mails of C are set in a lower plane than those of the figuring harness, by from $1''$ to $2\frac{1}{2}''$, but on an average $1\frac{1}{2}''$. Steel, brass, or copper mails are often used, but glass ones are preferable, as, owing to their smoothness, they do not cut the warp. These mails control all the crossing threads, and their lingoes vary from 4 to 10 per lb., for lingoes provide the only means by which crossing threads are put under tension. Any one, or any group of the 96 easers in each repeat, can be lifted separately to slacken the threads. Two parallel rods D, E, called the bridge, are bolted upon slotted brackets which permit of lateral adjustment. As a rule, they are from $3''$ to $4''$ apart, and are fixed horizontally beneath the warp.

The figuring harness F is about $12''$ in advance of the easing harness, and is built on the ordinary plan. It contains a sufficient number of mails to control every warp thread separately. Between the figuring harness F and the doup harness G a space of from $\frac{1}{2}''$ to $1\frac{1}{2}''$ is left to minimise the strain upon the crossing threads. The mail eyes of section G are about $\frac{1}{4}''$ lower than those of F, and sometimes contain two eyes for the doup twine to be drawn through, as shown at H, but when the doups wear out new ones must be built at the loom. At other times

mails are made with a single eye, and the doup twine is pushed through it as at I. The doups are then apt to fall out of the mails when the warp breaks. On the other hand, they can be readily replaced when worn out. Doup slips are made fast to a heald shaft J, which is raised every pick by cording it to the machine griffe, and J is pulled down by springs placed beneath the shaft. A doup requires careful adjustment, or it will rapidly wear out. By fastening regulating cords upon opposite ends of the shaft J, and tying them to the comber board, much strain may be taken from the slips, for the cords prevent the springs from pulling the leashes tight upon the mails. Doup lingoes vary from 16 to 24 to the lb.

Doup couplings have been attached to separate levers placed near the floor, and easing couplings have been connected to the rear ends of these levers. Each easing mounting thread, in one repeat of the pattern, was made fast upon a weighted lever situated above the easing comber board. Each lever normally acted to deflect the crossing threads upward, but by lifting a doup the corresponding easing coupling was pulled down to slacken the crossing threads. By adopting this plan a Jacquard is only divided into two sections, one for doups and easers, the other for figuring.

Two crossing threads are drawn through each easing mail C, Figs. 144, 145, after which both crossing and straight threads, 1 to 8, are drawn singly through mails of the figuring harness F. The first pair of crossing threads, 1, 2, are passed under the first pair of straight threads 3, 4 to the right, and then drawn through number 1 doup loop; finally, two straight and two crossed threads go through one dent in the reed. The crossing threads are thus drawn into the easing, the figuring, and the doup

mountings, while each straight thread only goes through an eye in the figuring harness.

To weave figure, the half heald J must be lifted, together with an assortment of threads in the middle harness F, as at 9. To form a cross shed, lift the half heald J, the doup

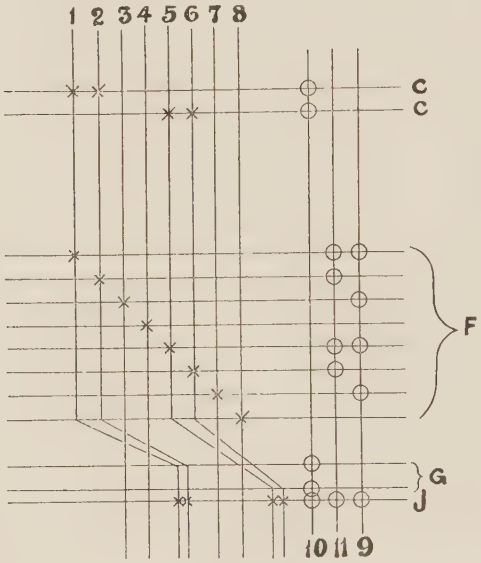


FIG. 145.

mails G that govern the threads required to cross, the easing mails C that slacken those threads, as at 10, also any assortment of threads in F for figure. To form an open shed lift the half heald J, the required crossing threads in the harness F, as at 11, and any assortment from F for figure.

With such a harness, variety of texture is almost limitless. The crossings may be of a most irregular description, including one crossing one, and one crossing eleven. The

picks in one gauze shed may differ from those in another at pleasure. Any doup can be brought into use at any time.

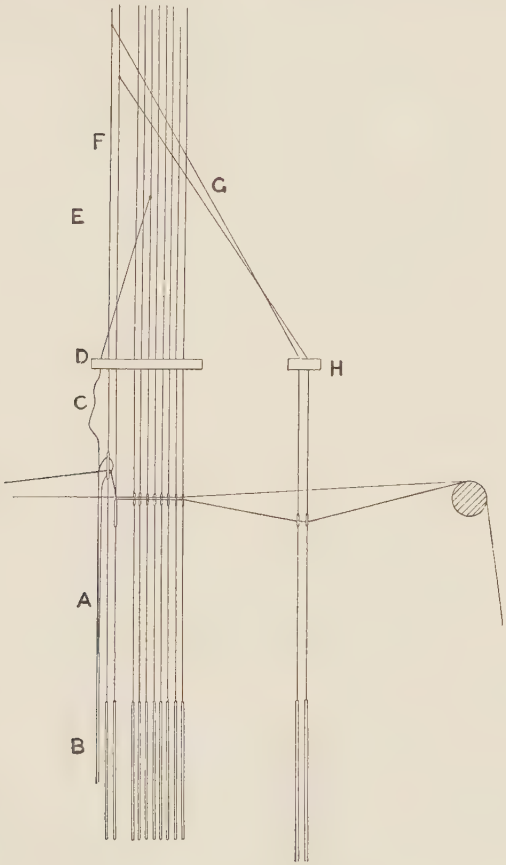


FIG. 146.

Warp and weft floats in the figure may be combined with the most varied ground weaves, provided plain cloth

surrounds the gauze, for it is essential that the warp shall be thoroughly opened out before figuring is attempted. If the warp is allowed to become slack, there is a tendency for the harnesses to twist at the mails, and cause entanglements in the warp threads. This is specially noticeable in the doup harness G, Fig. 144, where slack warp may permit the doup slips to twist round the doup mails to such an extent as to necessitate redrawing the warp into them before weaving can proceed. If, when manufacturing coupling twine, the twist in the united strands is not correctly proportioned to that in the single strands, the couplings will not remain stationary. Attempts have been made to produce stationary, or "dead," couplings by twisting the twine for the upper loops in an opposite direction to that for the lower loops, but the plan has only partially succeeded.

Another form of bottom doup harness is occasionally met with, which requires two sections in the Jacquard—one for doups and easers, the other for figure. Every doup slip A, Fig. 146, has a separate lingoe B, and a second thread C from the lingoe is led through a comber board at D, and tied upon those mounting threads in the figuring harness E, that control the same warp threads as the doup slip.

By this means a slip rises whenever its warp is lifted in the figuring harness. The doup mounting F is of the usual type, but slightly below the neck cords a mounting thread G is led from every thread F to the easing comber board H. Although this plan augments the figuring capacity of an ordinary Jacquard, it crosses the harness and increases friction. Fig. 147 shows two threads crossing two; the threads 1 to 8 fill the first row of the comber board D; 3, 4, 7, 8 are crossing threads

that pass through two easers in H, and two doups in F, while O shows the lifting for an open shed, C that for a cross shed, and P that for a figuring shed.

Top Doup Harnesses

Top doups are as extensively used with Jacquards as

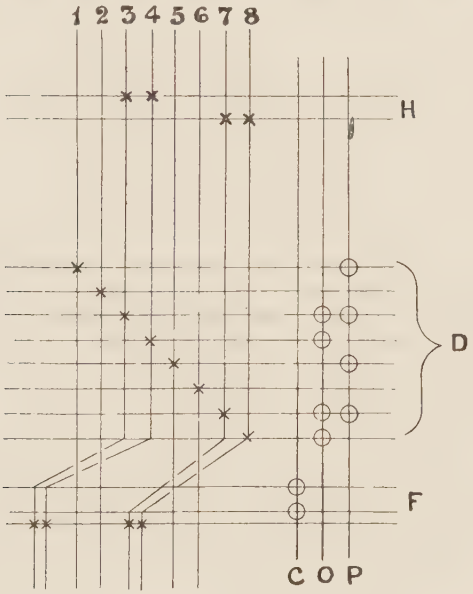


Fig. 147.

with heald shafts. A top doup harness differs from one for bottom doups—*a*, in having the half heald shaft fixed above the warp; *b*, in the doup lingoes being somewhat heavier; *c*, in the mails being approximately $\frac{3}{8}''$ higher than those of the figuring harness; and *d*, in the crossing threads passing above, instead of below, the straight

threads. The half heald shaft may be screwed to the doup comber board, or suspended from the Jacquard. In Fig. 148 the lines 1 to 8 represent warp threads that pass through mails in the comber board B. The crossing threads 3, 4, 7, 8 are drawn through four mails in the

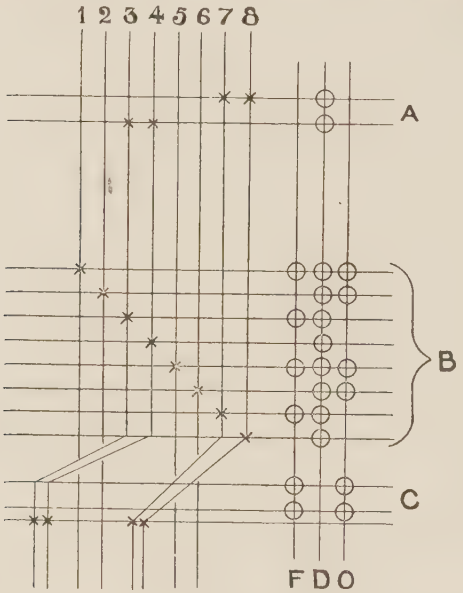


FIG. 148.

easing mounting A; through four mails in the figuring harness B, and through two loops of a half heald in the doup mounting C.

In the gauze portions of a texture an open shed O is formed by lifting the doup mails C, and the corresponding straight threads in harness B. A cross shed D is formed by lifting the easers A, together with straight and crossing threads in B. In the figured portions of a texture F, the

threads in harness B, that are required for figure, are lifted with the doup mails in C that govern those threads.

The chief differences between operating a bottom and a top doup harness consist in lifting the crossing threads for every pick of gauze with a bottom doup, and the straight threads for every pick of gauze with a top doup; also with the former, the doup and easer invariably move together; in a top doup this never occurs, for a lifted doup mail allows the crossing threads to become parallel, while the weight of a lowered doup lingoe is sufficient to hold them in the cross, but by lifting an easer the strain is reduced, and the straight threads are free to rise at the opposite side.

With a Jacquard of the type described on p. 268, the heads of either the easing or the douping hooks must be inverted, to permit a needle to press one hook clear of a griffe blade and to press the other over a blade.

The advantage of a top doup over a bottom one is that it is impossible, even with single-eyed doup mails, for the doup slips to fall out of reach of the weaver, and the doups are in the most convenient position to repair in case of breakage or disarrangement.

Top doups may be used when the crossing threads go under the straight ones, provided the crossing threads are lifted every pick; but the doup twine and the stationary warp rub as the sheds are formed; the doups also have a tendency to lift the straight threads off the race board and form irregular sheds.

If double lift Jacquards are used to operate gauze harnesses, shakers are essential. For bottom douping a shaker may consist in threading Bannister shafts (see Fig. 129) through those rows of couplings that actuate standing threads, and in causing those shafts to lift the standing threads slightly above the middle of the shed for every

pick. A tappet may be employed for the purpose. In Fig. 145 a shaft would be required for the couplings in each of the rows containing threads 3, 4, 7, 8 in the harness F. But since the threads in rows 1, 2, 5, 6 are crossing threads, it is unnecessary to add shafts to them.

For top douping the doup couplings may be knotted immediately above the doup comber board, and that board, and the doup heald, be lifted half a shed every pick. A tappet may also be employed for this purpose.

PART VIII

CARD-CUTTING

Designs are painted on paper which is ruled vertically and horizontally so that every space between two vertical lines shall represent a warp thread, and every space between two horizontal lines a weft thread. At regular intervals thicker up and cross lines, called bars, are ruled; the up lines enclose as many threads as there are needles in one short row of the Jacquard to be used. The cross lines mainly serve as guides to the designer and card-cutter. See Figs. 161 and 166. Paint laid upon the small squares, formed by vertical lines intersecting horizontal ones, denotes, as a rule, warp lifted above weft, and therefore holes in the cards.

Each card is cut from the painting found between two horizontal lines upon the design paper, but as holes are punched in the cards, they have the effect of turning up the design, bar by bar, into short vertical lines to correspond with the Jacquard needles.

Card-cutting machines are of two classes—*a*, those

used to transfer a pattern from design paper to cards; *b*, those used to duplicate sets of cards. Generally they are distinct, but occasionally they are combined.

The most familiar machines of both classes appear to be of French origin. The oldest method of cutting cards is used in districts where small Jacquards are the rule. It requires a pair of perforated plates which are hinged together, so that a blank card may be placed upon the lower plate, and the top one closed over it and locked by a sliding catch. Both plates are secured to a frame provided with rollers that run upon rails. A third plate is perforated like the others, but furnished with a handle at each end. It is placed on a bench, and the design to be copied is fixed behind it. Adjacent to the plate is a box containing several hundreds of cylindrical punches, all $1\frac{1}{2}''$ long by $\frac{7}{32}''$ in diameter. Each punch has an enlarged head for the purpose of preventing it from falling through the plate. The punches are dropped one by one into the holes in the carrying plate to correspond with the painted design; afterwards both plate and punches are fitted upon the other plates, and pressure is exerted to force the punches through the card. For this purpose a roller press is used, the roller being turned by one hand, while the plates are pushed beneath it with the other, or a power-driven press is used.

The process is more expeditious than might be supposed, especially where the groundwork of a pattern is regular, as in a plain or a twill weave. In the case of a plain ground all the punches are set for the first card, but after that odd picks only are cut during the first reading, because few punches require changing. On the second reading even picks are cut. A twill ground is read by repeats of the twill; thus for a four-end twill every fourth

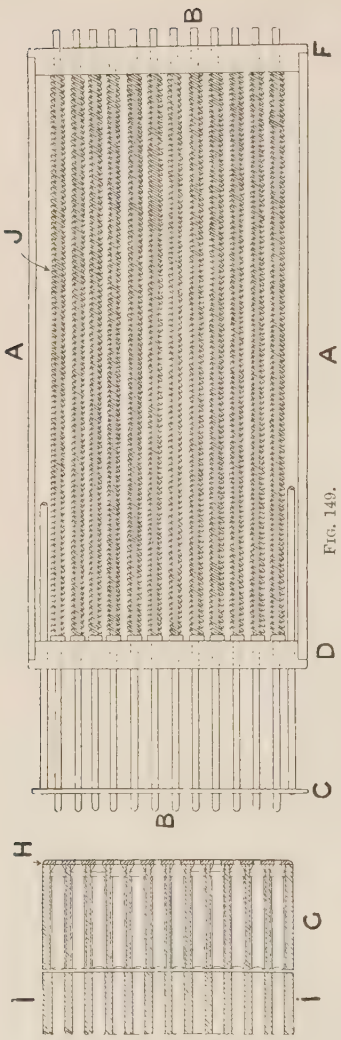


FIG. 149.

pick is taken at each reading. After all the cards are cut they are placed in sequence and laced together.

The above has been converted into a useful repeater by mounting a carriage on a frame so that it may slide to and fro. The carriage A, Fig. 149, generally contains 612 horizontal needles B, which are arranged in 12 rows of 51 each. Every needle is supported in front by two perforated plates C, D; the former is held away from the latter by riveting four spindles upon C, passing the spindles freely through holes in D, F, and threading spiral springs upon them. A similar perforated plate F is fixed in the rear of the carriage A to support the opposite ends of B. A shoulder, consisting of a piece of coiled wire, is fitted upon each needle to limit its forward movement, and also to permit one end of a coiled spring J to rest against the

collar, while the other end of J abuts upon the plate F. By this means the points of B are made to protrude through the plate C. A perforated box G is filled with punches that enter it head first. They are prevented from passing out at the back by a thin brass plate H, whose perforations are only large enough to permit the needles B to enter. Two studs are fitted in G to hold the carrying plate I, with its holes opposite those in G. The card to be repeated is held upon conical pegs in H, and the carriage A is drawn forward by depressing a treadle. Where holes are cut in the model card the springs J are strong enough to cause the needles B to push punches from the box G into the plate I, but solid parts of the card cause J to contract and the needles to recede. The carrying plate I, with the punches pressed into it, is removed to book plates containing the card to be cut, and all are led under a press either turned by manual or by mechanical power. After cutting that card, the carrying plate I is replaced upon the studs of G, and a comb, consisting of 612 pieces of wire fixed into a wooden back, drives the punches into the punch box G. A second card is fixed upon the pegs of H and the operations are repeated. This machine is reliable and simple, but compared with automatic repeaters, the process is slow and costly.

Reading-in and Repeating Machine

A "reading-in" card-cutting machine was patented in England by S. Wilson in 1821 from a foreign communication. It was for many years a great commercial success, but is now obsolete.

Shortly after its introduction the reading-in machine was converted into a reader-in and repeater, and from this model some of our best automatic repeaters have been

developed. It consisted of a series of 612 vertical cords A, Fig. 150, each formed with a loop at the bottom. A rod was passed through all the loops and forced into

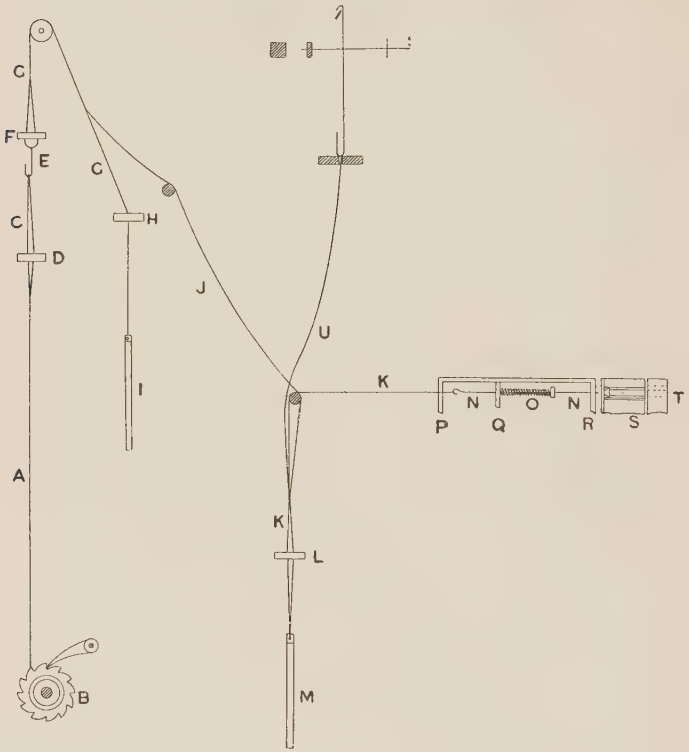


FIG. 150.

a slot in the roller B. At the top of A a second series of loops C were made by threading each cord through a separate hole in a guide board D, returning it through another hole in D and splicing it a few inches lower

down. After which the loops were severally dropped into wire hooks E that formed the terminals of another set of 612 cords G. These cords were held in one line by threading each through two holes in a fixed frame F. Each then passed over a guide pulley, through a comber board H, and was tied to a lingoe I. A third set of 612 cords J were spliced upon G, led over two guide rods, through a comber board L, and attached to lingoes M. From every lingoe M another cord K was drawn through a hole in a board L, then bent at right angles over a glass rod, and made fast to a needle N. Three perforated plates P, Q, R served respectively as front and back guides for the needles and the cords K. A collar twisted round N acted as a stop-hoop for a spiral spring O, and the rear of O abutted against a plate Q. A punch box S and a carrying plate T were fixed immediately in front of the needles N, as in the repeating machine. The lingoes M contracted the springs O, and pulled back the needles N. When any of the cords A were deflected, certain cords G, J, K were lifted to remove the weight of M from the needles N and thus permit some of the springs O to expand, and drive corresponding punches into the carrying plate T. The cords A were separated by a comb into sets of threads corresponding with the number of vertical spaces enclosed by bar lines on the design paper, and further divided by two rods to form an end and end lease. A straight-edge was placed across the design to assist the operator to read along a horizontal line. He proceeded to weave the pattern by interlacing cross cords, as picks, amongst the threads A in such a manner that every cord A representing lifted or unlifted warp would respectively pass in front of, or behind, a cross cord. When the cords A had been filled with picks, a roller was placed in the

position occupied by the top cord and fixed in a sliding frame. By pressing down a treadle the cords A in front of the roller were deflected and corresponding punches pushed into the carrying plate, after which it was ready for the press. The operation was repeated until all the cross cords had been removed from the vertical ones, and all the cards were cut. This completes the reading-in section of the machine.

For the repeating section a 600 Jacquard was placed over the comber board L, and a thread U from each hook was connected to its proper lingoe M. By suspending the cards to be copied from a cradle and leading them round the cylinder, the machine, when set in motion, lifted those lingoes M that corresponded with the holes in the card, and in each case a spring O forced its punch into the carrying plate T.

Vertical Punch Reading-in and Repeating Machine

By altering the form and position of the punches, a superior machine was obtained. All parts of the reading-in section remain precisely as in the former machine, and in Fig. 151 they are lettered from A to J. The Jacquard and its connections U also remain unchanged; but each cord K, after passing the glass rod, is led over a guide pulley L, thence down to a vertical punch N, which is approximately 11″ long by $\frac{7}{32}$″ diameter. Each punch is recessed on one side for $\frac{3}{4}$″ at two places P, Q, to leave a cylindrical piece $\frac{1}{4}$″ long between them. At O a recess of $1\frac{1}{2}$″ is formed on both sides of each punch, to receive a fixed comb R, having 53 teeth, of $\frac{1}{2}$″ deep. The teeth are thick enough to touch two punches without interfering with their freedom of vertical movement. The comb R

holds the slots P, Q in two adjoining rows of punches N facing each other, so that a vibrating comb S may be pushed through all the slots that fall in one line. Each

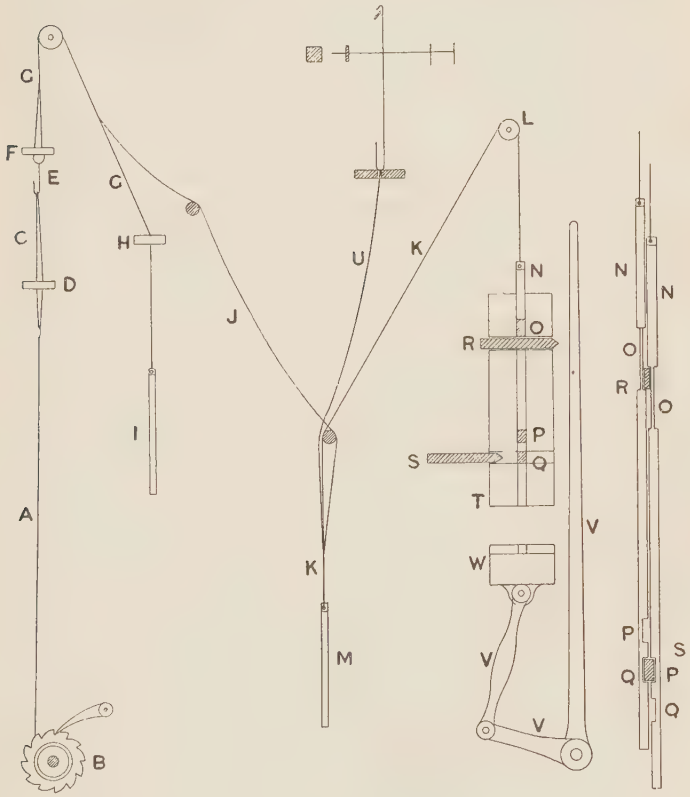


FIG. 151.

tooth of S will then lock two rows of 12 punches. This comb has 26 teeth, all $\frac{3}{4}''$ deep, and sufficiently wide to rest upon both lines of punches.

After withdrawing S, any of the cords, J or U, may lift the lingoes M, and the punches, normally supported by the weight of M, will fall until the slots P face the teeth of S, then as the latter advances some punches will be locked, with their ends protruding through the punch box T, while others will be retained in the box. See the enlarged, detached punches on the right of the Figure. A blank card is placed upon a perforated plate W, and by means of the compound lever V the plate W is carried up to T. On reaching the latter point every protruding punch will puncture the card, but those locked by S at a slot Q are inoperative. This machine is used on the continent of Europe, and embodies the essential features of the machine now made by Devoge and Co.

Devoge and Co.'s Repeater

Since Devoge's machine is merely a card repeater, the reading-in parts of the former are removed and only the Jacquard with its connections remain. A 600 Jacquard is fixed on an iron framing above a comber board V, Fig. 152, and cords U descend from the hooks to the lingoes M. Other cords K are attached to U, passed over rollers L, and made fast to the punches N. The latter only differ from the French punches in being recessed on both sides at P, Q, Fig. 151. By adopting this form of punch and furnishing the comb S with as many teeth as R, the makers claim that increased steadiness is given, because the punches are supported on both sides by S. The cards have peg and lace holes punched by a separate machine, after which they are laced into a continuous chain, passed over guide prisms and between the plates T, W. The Jacquard griffe rises, the comb S is withdrawn, and where lingoes M are lifted, the

punches N fall. In advancing, the comb S passes through the lower slots of lifted punches, and the upper slots of lowered punches, to lock them before the cutting plate W rises with the card to be perforated. The machine is rendered automatic by moving the plate W up and down with eccentrics, and the Jacquard griffe with a positive cam.

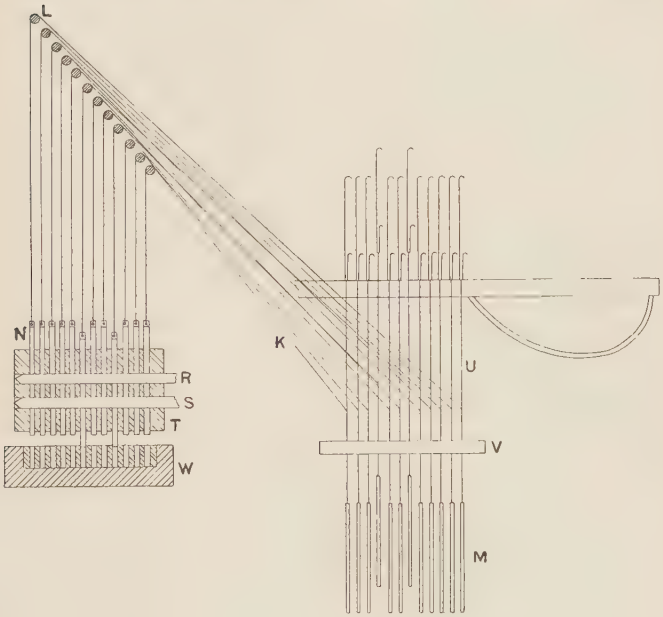


FIG. 152.

M'MURDO'S REPEATER

In 1887, J. M'Murdo patented a modification of the French machine, but since the punches receive a direct instead of an indirect action, compactness is combined with fewer parts.

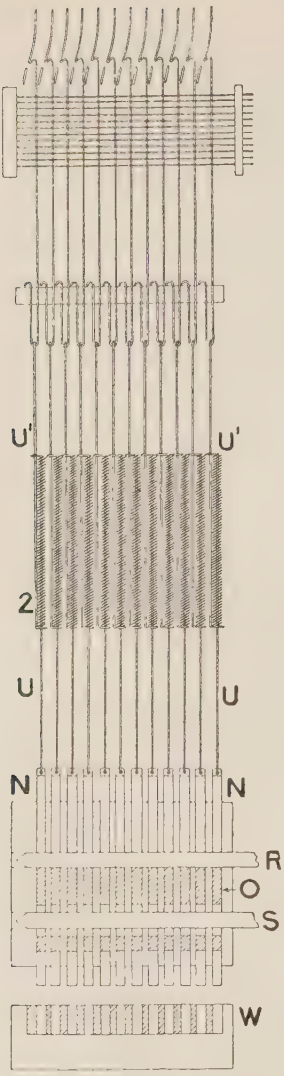


Fig. 153.

Above a punch box a 600 Jacquard is fixed, the heads of whose hooks face the spring box, and its griffe bars are set to miss vertical hooks and lift inclined ones. Two pieces of wire, U, U′, Fig. 153, are united to each other and to the hooks and punches. The piece U′ is flattened at the bottom, punched, and bent at right angles; U is similarly treated, then a steel spring 2 is threaded upon it; U′ is passed through the hole of U, and U through that of U′, with the spring 2 between the bends, thus forming a sliding joint.

The punches N are 11″ long, and recessed as usual at three places, but only on one side; the top recess O is $1\frac{3}{4}$″ long, the two lower ones are each $\frac{3}{4}$″, while the round portion between them is $\frac{1}{4}$″ long. All the recesses in two adjoining rows face each other. Both the combs R, S have 26 teeth; the former is stationary and prevents N from twisting, but S vibrates laterally.

Blanks in the cards to be copied cause the hooks to be

pushed over the griffe bars. The comb S is then withdrawn to permit the punches, operated by ascending hooks, to be lifted into the punch box. After which the comb S moves in to lock them either up or down, and eccentrics lower the punch box upon the stationary plate W. The sliding joints 2 permit of the downward movement; they also allow the griffe to rise slightly before the punches are liberated, and thus accelerate the action of N. When 400^s cards are to be cut, the needles in rows 1, 2, and 11, 12 are pressed back, and the surplus punches are lifted out of action.

Nuttall's Repeater

In 1875, James and Thomas Nuttall introduced an automatic repeater, which was both original and ingenious in construction. The upper part of this machine contains 612 needles A, Fig. 154, and the cards to be copied are moved by a cylinder D successively into contact with the needles. Holes in a card leave A unmoved, but blanks push them back. A set of 612 vertical wires B have an eye coiled at the centre and are mounted upon 12 fulcrum pins E. These wires connect an upper set of needles A with a lower set of needles C, and give C an opposite movement to A. The top row of A are united to the bottom row of C, and the top row of C are governed by the bottom row of A. Each needle C is furnished with a cylindrical plug, that in its normal position covers the head of a punch F and prevents it rising. Every punch so covered will be forced through the card to be cut at the next upward movement of the cutting plate H, but a blank in a model card withdraws a plug and allows its punch F to rise. The liberated punch rests by gravitation upon the blank card, but its weight is insufficient to make a perforation.

Twelve horizontal rows of 51 plugs are placed in tiers along a stepped, perforated plate K. Beneath the plugs are 12 rows of punches with heads varying in length to suit the positions of the plugs which act on them. Each punch has a collar I, formed at a uniform distance from the cutting point, and as H moves down to permit the next

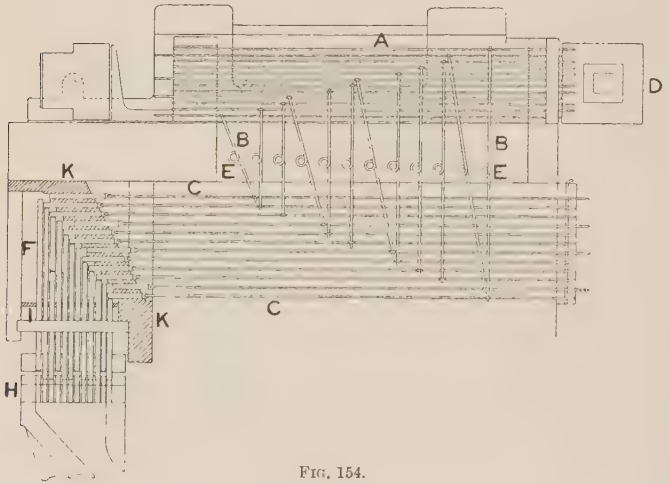


FIG. 154.

blank card to be brought into cutting position, the punches are suspended by their collars in a perforated plate.

As originally constructed, the vertical distance between plug and plug was insufficient, and in some cases vibration prevented a card from being perforated; in others, the cards were partially or wholly cut where they should be blank.

In order to reduce vibration, the punches F have been made so that one line acts slightly in advance of another line. Also, half the required number of punches have been

used, then two movements of the parts were needed to perforate a card. Thus the cylinder presented a card to be copied, and alternate rows of holes were cut; the cylinder then rose to bring the remaining holes of the same card opposite the needles, while the new card was moved laterally until blank places were under the punches, when a second series of perforations were made. Another machine of this type only cuts two or three rows of holes at one stroke. Messrs. Schaum and Uhlinger have simplified the machine by converting the wires C into hooks, and adding griffe bars at the extreme right of C, to withdraw the plugs from the punches. They also place the cylinder D beneath C, and cause it, in moving up and down, to operate vertical needles, and place the hooks in range of the griffe blades.

Hahlo, Liebreich, and Hanson's Repeater

In 1893 the above-named inventors patented a card repeater which has proved a commercial success. It is based on Nuttall's machine, but the modifications are material to its usefulness. Fig. 155 is an end, sectional, elevation. A is a shaft which is rotated from the first motion shaft by gearing. Upon A are six cams, four being employed to move the cutting plate B vertically up and down, and two grooved cams impart a swinging motion to a batten C and a cylinder D. The latter is accomplished as follows: Two runners are placed in the cam grooves; they are attached to two arms, and two links E unite the arms with the batten C. The cards to be repeated are passed round D in the usual manner, and are brought in rotation to face a set of needles F. Each needle operates a piece of metal G, whose basal end rests upon the head of

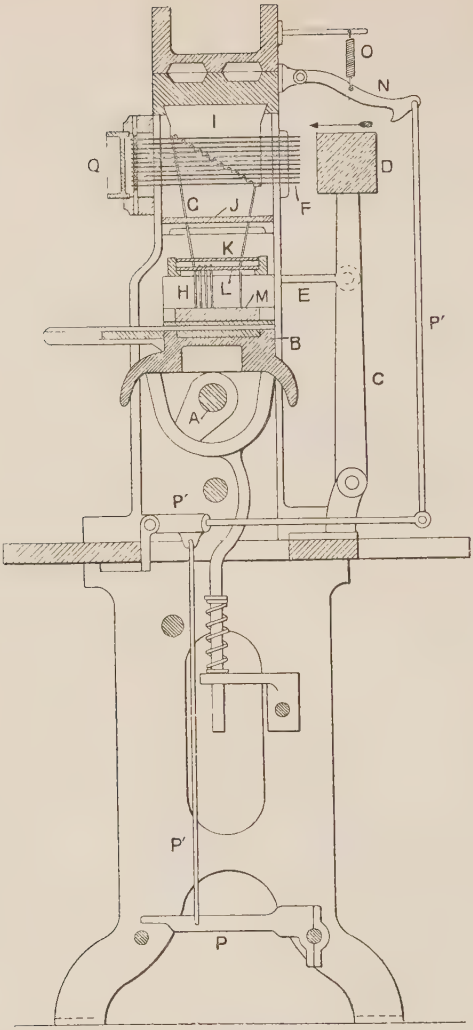


Fig. 155.

a punch H, while its upper end is normally held beneath a horizontal portion of a stepped plate I. The pieces G are kept in position by passing them through two plates J, K, and a stepped plate I is fixed between each vertical line of needles. In the event of a needle being pressed back by a blank portion of a card, the head of G is removed from its step. The punches H are suspended from a plate L, and their lower ends pass through a plate M. A blank card is laid in a sliding-frame which is pushed manually between the cutting plate B and the punch plate M. As the cams cause the plate B and the blank card to ascend, the punches H, and those pieces G that have been pushed from the steps in I, rest by gravitation upon the card and ascend with B. But where the pieces G are beneath their steps the punches are prevented from rising, and, as a sequence, are forced through the card. As the cams lower the cutting plate, the card frame is withdrawn from the punches, the perforated card is removed, a blank one is substituted, and the operation repeated. A card to be copied may be presented to the needles F any number of times in succession, for two catches N, employed to move the cylinder D through one-fourth of a revolution, are normally held above the lanterns of the cylinder by spiral springs O. When D is to partially rotate, a treadle P is depressed by the foot of the operative, and, acting through a lever and links P′, it lowers the catches upon the lanterns of D. Springs in the box Q thrust forward the needles F and the pieces G immediately the cylinder moves out. This machine punches a full card, including peg- and lace-holes, at one operation ; the peg-holes are, therefore, always true with the pattern holes. By its aid single cards can be cut, and cards can be repaired more readily than by most machines.

The Piano Card-cutting Machine

The "piano machine" is now in general use for cutting cards from designs. It consists of an iron table, from which two uprights rise to support a board, 52″ long by 20″ deep. A design is pinned upon this board, and two straight-edges traverse it from side to side; they guide the eye

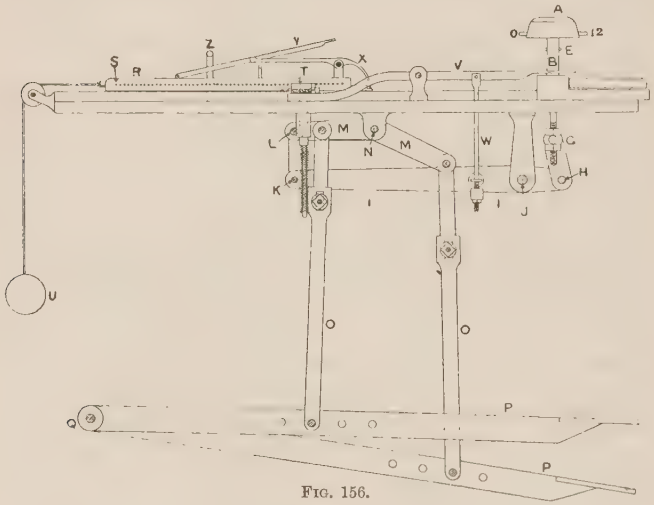


Fig. 156.

when reading along horizontal lines of a design, and may be moved up and down by screws that pass through nuts attached to each end of the straight-edges.

In the lower part of a head-stock A, Figs. 156 to 158, two perforated plates are bolted upon the table; the lower one cuts the card, the upper one guides the punches C, and a space is left between them sufficient to receive a card. Two holes are bored through the plates for the spindles B to work in. The spindles support a movable head-piece A,

in which a row of 12 vertical punches C are fitted to the gauge of the holes in a Jacquard cylinder. Each punch is $\frac{5}{8}''$ from top to shoulder, and $3\frac{1}{4}''$ from the shoulder to the bottom. In the centre, and immediately in front of the line of punches C, a peg-hole punch D is placed. The length of D is equal to C, but its diameter is $\frac{3}{8}''$. The shoulders of the punches C, D rest upon, and are lifted by, a guide plate E. Keys, numbered from 1 to 13, have square shanks and oblong heads; each shank is passed

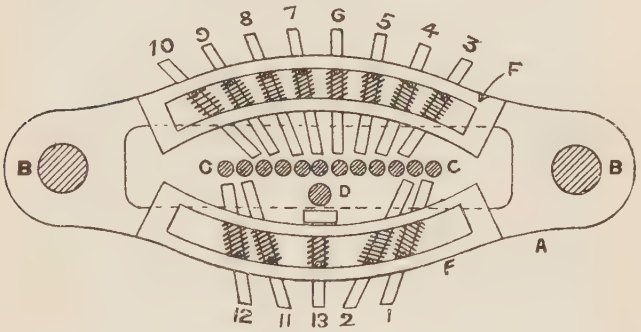


FIG. 157.

through one of two slotted plates F, and has a spiral spring threaded upon it so that one end of the spring may impinge upon a steel pin pushed through the shank, while the other end rests against the inner edge of F. When pressed in, a key covers a punch, and when the pressure is removed the spring carries the key clear of its punch. Keys 1, 2, and 13 are controlled by the right thumb, 3 by the little finger of the right hand, 4 to 10 by the remaining fingers of both hands, 11 and 12 by the left thumb.

The lower ends of the spindles B are secured by lock nuts to a cross head G, Fig. 156; the base of G is forked and

united by a pin H to a lever I, whose fulcrum is at J. A link and pins K, L connect I with a three-armed lever M, that moves upon a centre N. From the two remaining arms of M connecting rods O pass to two treadles P, which vibrate on a pin Q.

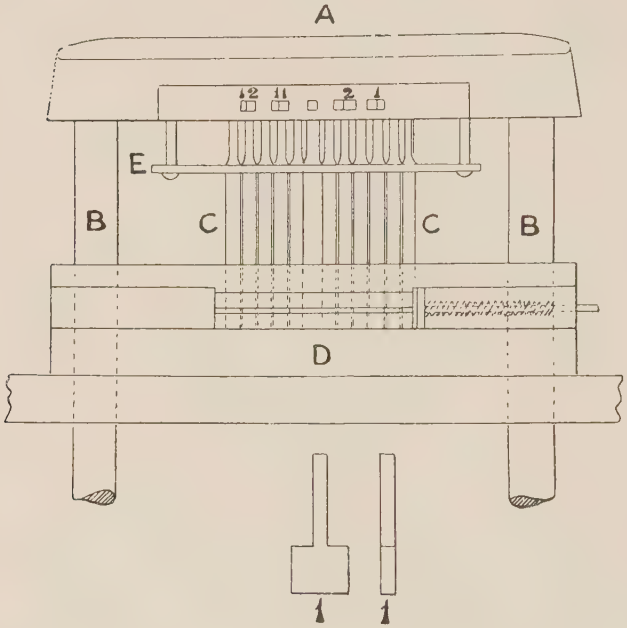


FIG. 158.

By pressing down the left treadle the head-stock A rises with the plate E and lifts all the punches C out of the gap between the two fixed plates. If a card is pushed between the plates and some of the keys are pressed in, a downward movement of the right treadle will lower the punches and force those whose heads are covered through the

card, while uncovered punches will be supported by, but will not perforate, the card.

Two smooth rails are laid down the middle of the table for the wheels of a carriage R, Figs. 156 and 159, to run upon ; R is moved by a rack of pins S, a slip catch T, and a weight U. The rack has a pitch equal to that of the Jacquard needles ; it is made by driving pins into a metal plate, and the plate is screwed along one side of the carriage.

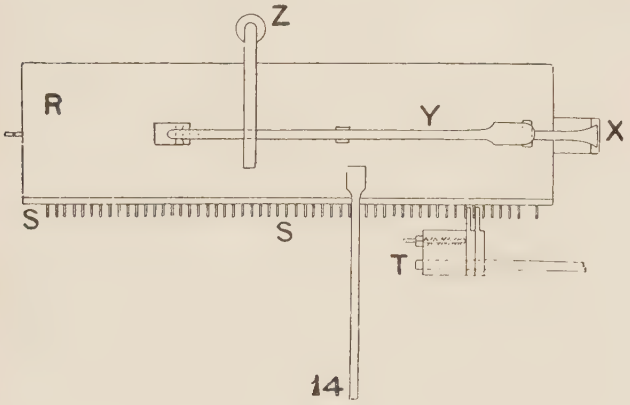


FIG. 159.

The shank of a slip catch T passes through the table top, and a helical spring is pinned upon it to hold it down. Two catches move amongst the pins, the upper one is fixed to the catch box, but the lower one is kept in advance of the upper one by a spring, shown in dotted lines. Each time the left treadle is depressed the box is moved vertically by a lever V and a rod W ; the sliding catch is thus placed between the teeth of S, the weight U contracts the spring in the slip catch, and the carriage R recedes one tooth from the head-stock. In front of R two nipper jaws X

are placed to grip each card fed into the machine. The operator sits in front of the head-stock with his feet upon the treadles. A card is pushed below the punches C and between two guide plates, situated in front of the head-stock A ; the nipper jaws are then opened by depressing the lever Y with the left hand, and the card is forced close to a stop and level with the guide plates. The jaws close and draw the card forward as the carriage slides, tooth by tooth, through the catch T.

One bar from the design is read, and one short row of holes is cut at each downward movement of the right treadle, also one pin in the rack S is passed as the left treadle is depressed. An index cord carrying a small weight is tied upon an arm 14 of the carriage, and is led by guide pulleys across the pattern board. A strip of card is fully perforated, numbered progressively above the holes, and nailed upon the board. When the carriage R is close to the head-stock, a knot is tied upon the cord, to face the first hole in the index card, and as the cutter works, this knot should always cover a number corresponding with a bar number on the design from which he is reading.

In order to prevent mistakes, cards are numbered progressively on the 26 side with a pen, a stamp, or an automatic numbering machine, and the number on a card and that on the design, for picks, must always be the same.

The numbered end is first pushed between the nipper jaws of the carriage R ; the peg- and lace-holes are cut, then bars from 1 to 26 may be used for the design ; a bar is left between 26 and 27 for the middle lace-holes, and bars from 27 to 51 are for the pattern ; but with bar 51 the last peg-hole is cut, and beyond that again the end lace-holes.

Attempts have been made to operate the head-stock automatically, but they have not met with general favour.

For a considerable time attempts have been made to construct a machine that will read cards from the design automatically, but up to the time of writing no such machine has passed the experimental stage.

Card-lacing

Before cards are ready for use they must be laced into a chain; this may be done by hand or by machinery. For

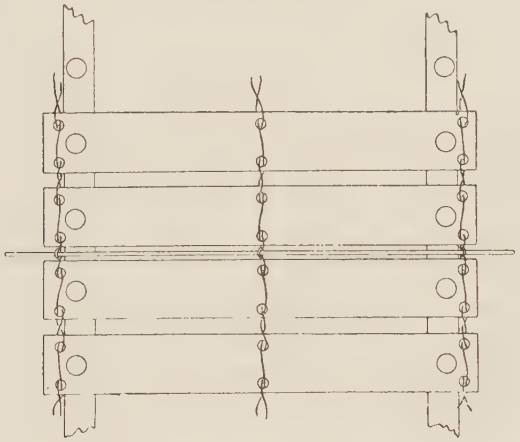


Fig. 160.

hand-lacing a frame is required which contains from 40 to 50 wood or metal pegs on each side. They are set to face each other, and to a pitch suitable for the width of card to be laced. The cards are placed in rotation upon the pegs, and the lacing is threaded through the lace-holes with a needle but is crossed over from right to left between every pair of holes in one card, and also between two adjacent cards, then back again in the same order, as shown in

Fig. 160. The defects of this plan are due to inequality in the tension of the lacing, an excessive number of knots, and the time taken to do the work.

Lacing is of different kinds and used in different conditions. It may consist of single or folded cotton or linen twine, of plaited tubular banding, of narrow braid, or of woven tape, and these materials may be used without subsequent treatment, but most of them are soaped, or saturated with boiled linseed oil. In any case they should be strong, supple, and not readily influenced by atmospheric conditions.

Lacing-Machines

Inventors have constructed automatic lacing-machines on the principle of a compound sewing-machine. In the earliest machines cards were sewn together in two or three lines simultaneously, by forcing needles through them and locking the needle threads on the under side with shuttle threads. The number of stitches in each card, the inequality of the tension on the twine, and the lack of flexibility rendered the inventors' efforts fruitless. W. Nuttall, Count Sparre, Stahlknecht, the Singer Company, Messrs. Reid and Fisher, Parkinson, and others, have laboured upon the problem with more or less success. Count Sparre was one of the first to pass needle threads through the lace-holes of a card, and to link shuttle threads into them.

One machine punches peg- and lace-holes, and laces simultaneously. Each thread of lacing is placed above one card and beneath the next; both are linked at the lace-holes, and crossed between card and card. Under these conditions machine-lacing does not differ greatly from hand-

lacing, except that in most of the former the threads are crossed in one direction continually.

Reid and Fisher, in 1888, and subsequently Parkinson, by improvements in details, have produced a lacing-machine that bids fair to supersede the hand process. By its aid 900 to 1000 cards can be laced per hour, from 400 to 700 without a knot, and the tension is also under control. This machine has been arranged for from 2 to 5 lines of lacing, and for cards from 8″ to 40″ long by 1″ to 4″ wide. When lacing 400^s or 600^s cards, three lock-stitch sewing-machines are employed, to pass lacing through the usual lace-holes. The cards are fed upon conical pegs inserted in endless chains, and the chains are drawn forward at a speed suited to the breadth of the card.

The Singer Company have introduced machines for various widths of cards in which an effect very similar in appearance to hand-lacing is produced. In a 600 card 4 holes are employed in each line of lacing, viz. 2, 4, 9, and 11, and the result appears to be quite satisfactory. Tapes have been secured to cards by metal staples, and by glue, but they were not sufficiently flexible at the joints. Cards have been notched at both edges, facing the lines of lacing, and the upper and lower twines twisted between the cards to form loops, each loop enclosing a card and holding it in position.

Card-wiring

Cards are suspended from cradles by wires which project about $1\frac{1}{4}$″ beyond both ends of the cards, as in Fig. 160. These wires are usually tied upon the lacing with waxed band to prevent slipping, but they are sometimes pushed between the two lines of lacing before being tied. If the

wires are not laid upon the face of the cards they touch the cylinder and form an uneven bed for the cards to rest upon. The distance from wire to wire is determined by the vertical and horizontal spaces available at a loom. Some wires are only 12 cards apart, but 16 to 24 are more general.

Card Cradles

A card cradle consists of two pieces of curved metal which are secured beneath a Jacquard cylinder so that the cards will drop between them (see Fig. 152). But the space between the metal supports does not exceed the length of a card by more than $\frac{3}{8}''$ or $\frac{1}{2}''$, hence the wires are caught, and the cards prevented from falling to the floor. The bend of a cradle should be such as will prevent the cards from falling upon each other, and as fresh cards are taken up from the rear of a cradle, those remaining should automatically slide down into the vacated places, and thus leave a free fall for the descending cards. Provided sufficient firmness and holding room are given, the sectional shape of a cradle is unimportant.

PART IX

LAPPET SHEDDING

Lappet weaving is a species of embroidery by which various colours and patterns may be produced simultaneously upon any foundation fabric, but plain or gauze weaves are often employed, for with those weaves the

warp threads are not readily disturbed by a side pull from the "whip" threads. Lappet weaving consists in moving whip, or special warp, threads from longitudinal to transverse positions, and in lifting each over a pick of weft, to fasten it at both ends of every horizontal line, but the whip threads float loosely between the terminals. Although there are definite limits to lappet figuring, it is quite possible to produce extensive figure effects by skilful designing and the use of several lappet frames.

A lappet loom differs from a loom of the ordinary type in the following respects: *a.* A groove is formed between the reed and the race board which is wide enough to receive pin and needle bars. *b.* A lappet wheel is needed, together with mechanism for operating it. *c.* Driving cranks have from 6″ to 7″ sweep; the larger sizes usually accompany three or four sets of needles, and they are sometimes placed outside the loom framing in order to leave the reed space clear and permit the sweep to be varied. *d.* A slightly longer stretch is also desirable. *e.* A separate whip roll is required for each needle frame, and these may be placed above the warp beam, below it, or in both positions, as may be found most convenient. Each roll is separately controlled by cords and small weights. *f.* A special tensioner is provided for each whip roll.

The Scotch type of lappet loom is in most general use. Its needle bars are moved vertically in, and horizontally by, shifter frames; a large wooden wheel has grooves cut in one face, each to receive a feeder or peck, and it is driven forward one tooth on alternate picks. Each shifter is moved in both directions by the dead weights of levers, and through spaces regulated by the breadth of a groove

in the lappet wheel; an upward movement in both pin and needle bars is derived from the rocking shaft.

A lappet wheel is made of sycamore, or other close-grained hard wood, and is mounted upon the slay behind one of the shuttle boxes. Aluminium has also been used in place of wood. It has an irregular groove, or grooves, cut in one face to limit the lateral movements of the needle bars. The diameter of a wheel is not of great importance, provided it is large enough to prevent the grooves from becoming worn by frequent contact with the peck.

A wheel is made by turning a disc of wood to the diameter and thickness required, say, 13″ by 1″. A comb having a pitch that bears a definite relation to the reed, generally half as fine, is pressed against the revolving disc to describe a series of concentric circles on one face. The circumference is next equally divided by radial lines which are equal in number to the horizontal spaces on the design: see Figs. 158 and 159; of these Fig. 158 is the design and Fig. 159 the lappet wheel; C are the concentric circles, D, D are 32 radial lines which correspond with the 16 horizontal spaces of the design twice repeated. Each space between two radial lines equals one tooth, or two picks of weft in the fabric. A vertical space in the design represents two, and a circular space C in the wheel four warp threads. By comparing Figs. 158 and 159 it will be found that the breadth of each groove at number 1 and following numbers agrees with the design after a

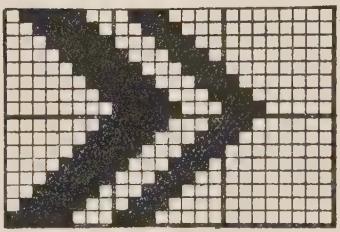


FIG. 161.

predetermined allowance has been made for the thickness of the peck, say two dents. A groove must be cut in B, to the exact dimensions of the marks made upon the radial lines. Two, three, or four patterns can be woven from one wheel by cutting additional grooves inside or outside

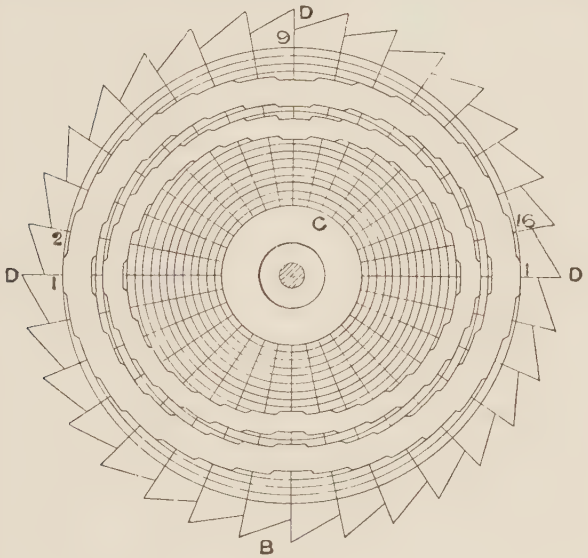


FIG. 162.

the first one as shown, but beyond this a new wheel is needed for a new pattern. A tooth is cut on each space between two radial lines D.

In case the lateral movement of a needle bar is positively controlled, a wheel is moved every pick, the pattern grooves then being only wide enough to receive a peck, but they meander over the wheel surface.

A hole is bored through the centre of a wheel to receive

a hollow boss formed on a circular metal plate, and the plate is screwed upon the rear of the wheel. A portion of the rim is removed to the depth of the teeth to provide a brake surface about $\frac{3}{8}''$ wide. In this a ring groove is cut for a string which is first tied to a fixed bracket, then led into the upper part of the groove, and finally made fast to a spiral spring. See Figs. 163, 164. By regulating the pull of the spring a wheel can be prevented from overrunning when acted upon by a turning catch. A ring groove is also cut in the back of a wheel for each detached pattern, and two or more strips of metal are pressed into each groove. The strips vary in length to suit the stationary periods of the needle bars, for each space separating two strips equals an active period of a bar. The strips in the first groove stand out from the wheel about $\frac{1}{4}''$, but those in other grooves project a greater distance, because the hooks they act upon are further from the wheel than that for the first groove.

The accompanying figures show the mechanism of a lappet loom as made by the Anderston Foundry Company, Glasgow. A wheel A, Figs. 163 and 164, is mounted upon a stud which is bolted in a slotted rail attached to the swords. A is rotated intermittently by a bowl B fixed in an arm upon the bottom shaft. B depresses a wooden lever C once in two picks. A connecting rod is hooked into an eye bolt in C, also into a hole in a cranked lever D. The short arm of D passes through a slot in the catch-holder E. As C is depressed, the cranked lever D lifts a spring catch F over a tooth in the wheel A. So soon as the bowl B moves off the lever C, a spiral spring G pulls the catch F down, moves A one tooth inward, and lifts the lever C. A spring is employed because it can expand in case of obstruction, and prevent a smash. These movements

occur when a peck is passing from the outside to the inside

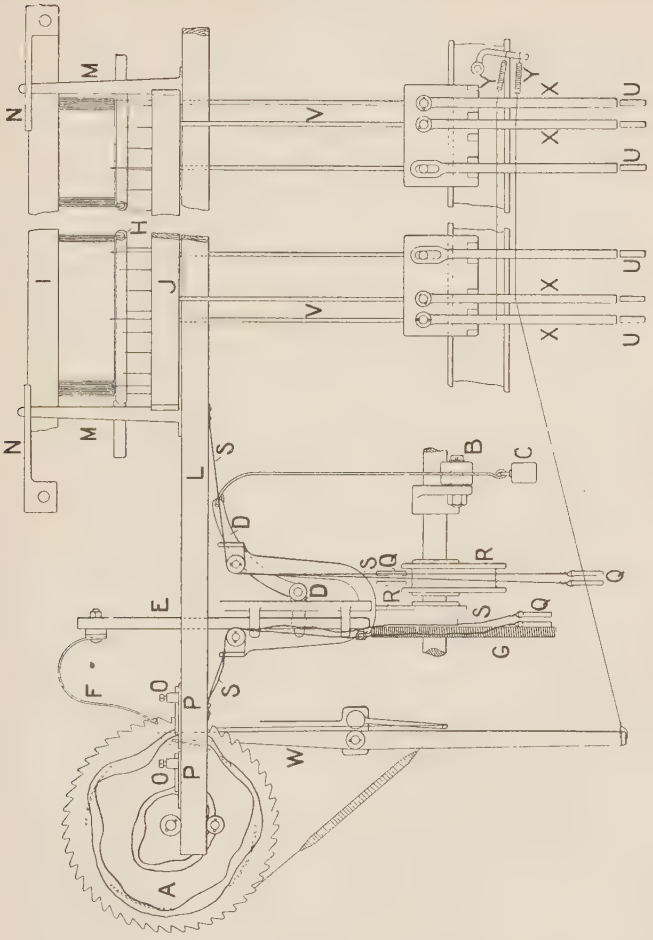


Fig. 163.

of a groove, and when the cams employed to slide the shifter frames are midway in their lift, for at that instant

all strain is taken from the pecks. A peck P is adjustably attached to a shifter frame for the purpose of moving a needle bar laterally.

A pin bar and a series of needle bars are placed in a groove in the slay as follows: The lower rib of a reed

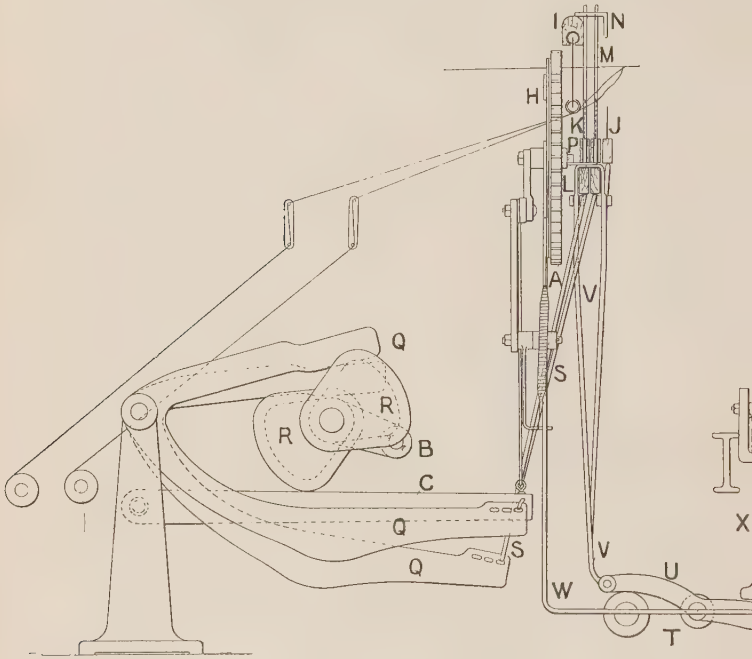


FIG. 164.

is fitted in a semicircular metal trough H, which is bolted upon the rear of the slay swords; the upper rib is secured in the slay cap I, but that cap is also bolted behind the swords. This leaves a space between the reed and race board of 3″ for the reception of one pin bar J, and four needle bars K, only two of which are shown.

For a 42″ reed space loom, a pin bar consists of a lath $1\frac{1}{2}$″ deep, $\frac{7}{16}$″ thick, and 44″ long. Into the upper edge of this lath a number of stout pins are driven $1\frac{3}{16}$″ apart. They stand out from the bar $2\frac{1}{8}$″ and are pointed at the top. The bar is tipped at each end with a vertically grooved piece of brass; these brasses fit upon iron slides mounted in the inner ends of the shuttle boxes. The bar is also lined with iron along the bottom edge at two places where the lifting rods act upon it. The pins are set to touch the race board, for they serve in lieu of a reed to guide a shuttle. As the slay recedes from and advances towards the cloth fell, the pins rise above and fall beneath the line of warp.

A needle bar K is made of wood $1\frac{1}{2}$″ deep by $\frac{7}{16}$″ thick, and 45″ long. Where the lifters act upon K, it is lined with metal along the under side; it is also tipped with grooved brasses which fit freely over the slides M in such a manner that a vertical lift can be imparted without side movement. Steel or brass needles, driven into the wood, stand out $2\frac{3}{4}$″. They are smooth, flattened at the top, pointed and punched to form eyes for the whip threads to pass through. The exact number and positions of the needles are determined by the size of the pattern and the number of times it is repeated on the width of a fabric. Thus pattern A, Fig. 166, has 32 dents to a repeat. If the reed has 20 dents per inch, and 37″ of cloth are to be covered with pattern, $37 \times 20 = 740$ dents occupied by warp. $740 \div 32$ dents per pattern $= 23$ patterns. Therefore 37″ of a bar is divided into twenty-two equal parts, and a needle is driven in at each mark. Every bar has two movements—namely, a lateral one to bend the whip threads into a transverse position, and thus form a pattern, and a vertical one to lift the threads above a moving

shuttle. Lateral movement is derived from the wheel A, which permits the shifter frames to slide to and fro, but their maximum traverse is determined by slots in two steadying plates N.

Each needle bar is mounted in a separate shifter frame L, consisting of a lath 72″ long, $1\frac{1}{2}$″ deep, and $\frac{1}{2}$″ thick. Upon its top edge two metal slides M are screwed 45″ apart to work in the slots of N. A shoulder is formed upon a slide immediately beneath a plate N to prevent it from moving vertically. The plates are fitted in front of the slay cap; each is provided with four parallel slots, $4\frac{1}{2}$″ long by $\frac{7}{16}$″ apart. In order to facilitate lateral movement, the frames L are lined along their lower edges with metal in three places, and the metal rests upon three antifriction bowls. Near that end of each shifter which faces the lappet wheel A, a flanged brass plate O is screwed upon its upper edge, and between the flanges of O a peck P is fixed by a pinching screw. A peck is a piece of metal which is square in section, but bent at right angles to permit it to enter a groove in A, and there it is cylindrical.

Shifter frames are moved conditionally by cams, in the following manner: The upper and shorter arms of eight levers Q, only four of which are shown, rest by gravitation, in sets of four, upon the faces of two flanged cams R. Both cams are fixed upon the bottom loom-shaft, outside the framing, and adjacent to each other. They are set as for plain weaving, with the large face of one and the small face of the other uppermost at the same time. From the forward end of each long arm in the outer set of levers Q, a strap S is led to a guide pulley situated beneath a shifter frame L. The straps are deflected outward at the guide pulleys and are severally screwed upon the bottom edges of four shifters. From

the forward ends of the inner set of levers Q, four similar straps are led over corresponding guide pulleys, but they are deflected inward and screwed upon the shifters. As the cams rotate, all the shifters move simultaneously to the right or left; for as one set of levers fall they tighten one set of straps, and slide the shifters away from the wheel. When the other set of levers fall they tighten the remaining straps and slide the shifters towards the wheel. This movement is made in about $\frac{1}{8}$ of a pick, but the distance travelled is regulated by the breadth of the slot in the wheel; for once a peck reaches the edge of a groove, that lever remains suspended by its strap until again lifted. Lateral movement begins when the needle points are below the bottom line of warp, and the reed in moving forward is approximately $\frac{1}{2}''$ from the cloth fell; it must end before the vertical movement begins, and the needles should be fully lifted when a pick is delivered.

Both pin and needle bars are moved vertically by two brackets T upon the rocking shaft; in the forward end of each bracket a stud is held by a pinching screw. Each stud serves as a fulcrum for five levers U. To the rear end of each lever a rod V is attached. Of these rods the first pair, namely, the outer ones on each side of the loom, are led behind the fourth shifter L; they are flattened at the top, bent at right angles, and passed between the fourth shifter L and its needle bar K. The second pair of rods are led in front of number one needle bar, and are also bent and flattened, but pass between number one shifter and its needle bar. The third pair are cylindrical; they are straight at the top and placed beneath the pin bar. The fourth pair are led between number one and number two shifter bars, and are bent backward to go between

number two shifter and its needle bar. The fifth pair of rods are passed between the second and third shifter and bent under the third needle bar. When the needle and pin bars are in their lowest positions, the rods V should be midway between the needle bars and shifters, without touching either.

As the rocking shaft vibrates, the levers U rise and fall with their fulcra, but they can either lift the rods every pick or leave them stationary. When lifted, the bent ends of the rods thrust up the needle bars until whip threads, in the needles, are level with the top line of ground warp.

In case detached figures are diapered over the foundation cloth, the needle bars must be put out of action. This is controlled from the lappet wheel, into the rear of which strips of metal have been inserted as previously explained. Four strips are shown by dotted lines on the wheel A, in Fig. 163. A strip holds back the head of a long catch W, and while so held a needle bar will be inoperative. A space between two strips of metal permits the head of W to move over the end of a strip, and the needle bar at once becomes active. Thus, a cord from the lower end of the catch W is made fast to a pair of pendents X. The pendents are centred at the top and, when W vibrates, they are drawn by the cord away from the surfaces of two levers U. On the next backward movement of the slay the levers' fulcra are lifted and the forward end of each uncovered lever rises, but their rear ends remain undisturbed. A spiral spring Y is hooked into a rod situated on the opposite end of the loom to the lappet wheel. In contracting, Y draws back the pendents until they assume a vertical position. Each then covers the forward end of a lever. As the slay again recedes the fulcra of U will be once more raised, but this time the forward ends of the

levers are locked; consequently, their rear ends ascend, and the rods attached to them lift a needle bar.

Ten pendents X are arranged in two sets of five. The middle one in each set is securely bolted in a vertical position to operate the pin bar, which must rise and fall every pick. The remaining eight control eight levers U, eight rods V, and four needle bars K. Each pendent is bent inward at the base to ensure correct contact with a lever, and all are normally vertical. A long catch W is needed for each bar K that has to rise and fall intermittently; a rod limits the inward swing of W, and thus prevents breakages which would occur if the heads of W passed inside the metal rims.

The lappet wheel, the driving catch with its spiral spring, the cranked lifting lever, and the long catches are all mounted upon, and swing with, the slay.

Whip threads pass from whip rolls without being drawn into either healds or reed; they are led between the wires of a tensioner, between the leashes of the shedding harness, beneath the reed, and through the needle eyes. As a bar K rises and falls, these threads vary in length between a whip roll and a needle eye, and one of the most important points to be attended to in lappet weaving is the regulation of tension upon them. Delicately adjusted wires provided for the purpose are shown in Fig. 165. They consist of two wooden end pieces each $\frac{1}{2}''$ thick by 4″ long and 1″ wide. Two parallel pieces of wire B are securely fitted into the end pieces at a distance of 3″ apart, and they are long enough to reach across the warp. Two holes are drilled in both end pieces at equal distances from their centres, and cords C, D are threaded through them, twisted, and tied upon two flat springs which are bolted to the loom framing. The whip threads

pass in front of the upper and behind the lower wire B, and the degree to which the cords C, D are twisted determines the efficiency of B to give off and take back whip in unison with the rise and fall of the needles. If whip threads are to remain tight without fraying the foundation fabric at the edges of the figures, careful regulation of the twists in C, D is essential. A simpler and in some respects a more satisfactory tensioner is made by bolting two brackets to face each other upon the end framework, at a height of $2\frac{1}{2}''$ to $3''$ above the warp line. Each bracket has four holes to receive four parallel

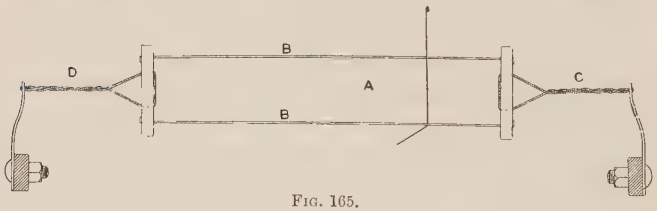


FIG. 165.

elastic bands which are stretched from bracket to bracket. The whip threads from each roll pass over a separate band, and as the tension varies the bands stretch or contract.

A lappet wheel may take the form of a hollow cylinder with a series of varying indentations cut in its front edge. Such a cylinder is rotated by a ratchet and pawl tooth by tooth. A feeler lever is then fulcrumed at the centre, and its lower edge is held by a spiral spring against the irregular face of the cylinder, but its higher end is made fast to a needle bar. Hence the feeler vibrates in unison with the ridges and hollows of the cylinder, and transfers the movement laterally to the needle frame and whip threads.

A cylinder is built up of close-grained wood, and filled

in at one end to enable it to be fixed upon a ratchet wheel. Its periphery and front edge are turned true and smooth, then as the cylinder rotates in a lathe the teeth of a steel comb are pressed against it. By this means a series of parallel lines are scratched along the surface. Its periphery is next divided into a number of equal parts to correspond

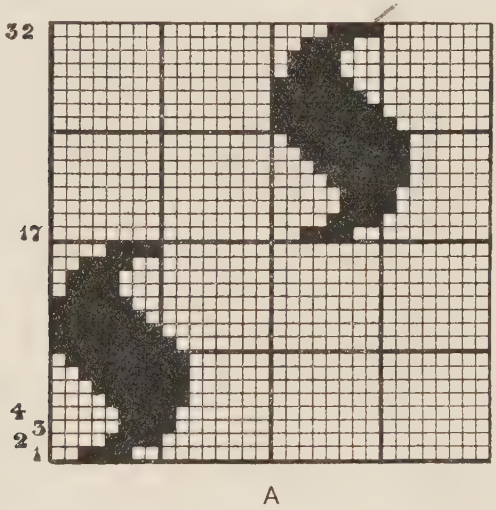


FIG. 166.

with the picks in one repeat of the pattern to be woven, and lines are drawn through each point, parallel with the cylinder axis.

For example, Fig. 166 is a design in which each vertical space represents a dent, and each horizontal space two picks; and Fig. 167 is the periphery of a lappet cylinder when opened out. The thin vertical lines C are those scratched by the comb teeth; they are indefinite in number, but equal in pitch the space occupied by two warp threads

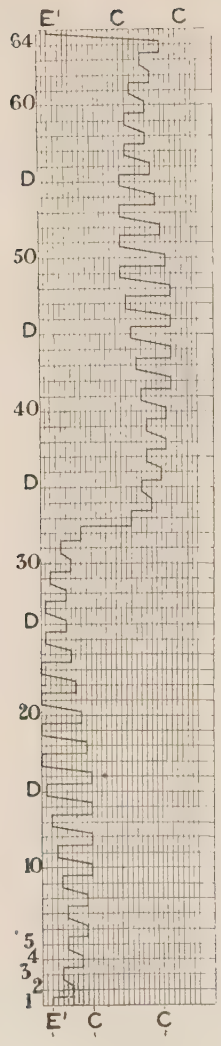


FIG. 167.

in a fabric. The horizontal lines D are parallel with the cylinder axis. Thirty-two horizontal spaces on the design paper A give one repeat of the pattern, but as each line of whip must be fastened at both ends of every float, 64 picks will equal one revolution of the lappet wheel; hence there are 64 spaces D, and 64 teeth in the ratchet wheel. The thick lines E' show the form of cylinder end required to reproduce pattern A on a cloth.

In the first horizontal space of A, Fig. 166, and on the first line of D, Fig. 167, two dents, or spaces, are passed in each case to find the starting-point of the figure, which at 1, A, floats over four dents, and 2, D, is four dents lower than 1, D. Therefore a feeler will move a needle frame through a space of four dents.

On 2, A, four dents are passed, and four taken for the pattern. On 3, D, four dents are also passed over; then on 4, D, four more dents are taken, and so in like manner up to 16, A, and 32, D, where the first spot ends. At 17, A, eighteen dents are passed and four taken. At 33, 34, D, the same order is maintained.

In many detached spots, such as A, it is necessary to add binding to

each figure by moving the whip threads across a single dent immediately before a spot begins and ends, for this prevents the whip threads from being pulled out of the foundation weave. In such cases eight extra teeth must be provided in the ratchet wheel, and eight extra horizontal spaces on the cylinder, for each stitch equals two picks of weft in the piece. If a lappet pattern is to be free from defects, accurate marking and cutting of the wheel are essential.

For two patterns, another cylinder is required and it is usually fixed in a corresponding position on the opposite side of a loom. Where both patterns repeat on the same number of picks, or where one is a multiple of the other, mechanism may be economised by securing two cylinders upon a single ratchet wheel, one inside the other. Two feelers that move horizontally are then employed, each to be acted upon by one cylinder only, and connected to a separate needle bar.

A feeler that slides horizontally is superior to one that moves in the arc of a circle, because the latter will carry different parts of its surface into contact with the lappet wheel, and impart an inaccurate traverse to the needle bar. It is usual to employ a cranked lever and a cam to withdraw sliding feelers from the surfaces of lappet cylinders before rotation commences, for by this means friction and wear are reduced.

Instead of a cylindrical drum, a disc may be drilled at regular distances so that the holes form one circle, or two or more circles, and one pattern, or two or more patterns, may be formed by securing pins of various lengths in the holes. Provided the disc holes are a multiple of the design, such a wheel has the advantage of permitting many different designs to be woven by readjusting the pins.

Pegged lattices are used in various ways to actuate needle frames. If they are placed beneath the harness and parallel with the driving shafts, a number of feelers rest upon the lags, and the movements of the feelers vary with the lengths of the pegs. These movements are transmitted to the needle bars by links and cranked levers. One of the simplest lattice contrivances is of American origin. It consists in leading a set of metal lags above the shuttle box, and in causing metal pegs to press directly upon the needle bar shifters. As a rule the pegs do not vary in length to suit a particular count of reed, but are used with all reeds; the effect being that floats are of uniform length, but the number of dents passed over varies with the reed.

In the drawings here given the needles point upward, but in practice many point downward. In the former case the figure will be woven face down, in the latter face up: it is an easy matter to thread needles that point downward, but a difficult one to draw threads through the reed.

The consumption of whip largely exceeds the length of cloth woven; the difference depends upon the pattern. To determine the length required for a given length of fabric, the design must be counted to find how many dents the figure covers at each traverse of the needles; and when the sum of all the movements is obtained, the number of yards of whip, for one yard of cloth, can be found by the following rule:—

$$\frac{\text{The number of dents per pattern} \times \text{the number of needles in a frame} \times \text{the number of repeats of the pattern in one yard of a fabric}}{\text{The dents per inch in the reed} \times \text{the number of inches per yard.}}$$

Take as an example Fig. 166, in which there are 32

horizontal spaces, and assume 23 needles in a frame, 20 dents per inch in the reed, and 40 picks of weft per inch in the fabric.

The lines of whip vary as follows: The numbers in the second column are the dents passed over, as shown by the horizontal spaces; those in the third column are the dents crossed in moving the needles back to the starting-point on the next line.

Number	1 = 4	dents	+ 2	dents	= 6	dents
,,	2 = 4	,,	+ 3	,,	= 7	,,
,,	3 = 4	,,	+ 4	,,	= 8	,,
,,	4 = 4	,,	+ 5	,,	= 9	,,
,,	5 = 6	,,	+ 7	,,	= 13	,,
,,	6 = 7	,,	+ 8	,,	= 15	,,
,,	7 = 8	,,	+ 9	,,	= 17	,,
,,	8 = 9	,,	+ 10	,,	= 19	,,
,,	9 = 9	,,	+ 9	,,	= 18	,,
,,	10 = 8	,,	+ 8	,,	= 16	,,
,,	11 = 7	,,	+ 7	,,	= 14	,,
,,	12 = 6	,,	+ 5	,,	= 11	,,
,,	13 = 4	,,	+ 4	,,	= 8	,,
,,	14 = 4	,,	+ 3	,,	= 7	,,
,,	15 = 4	,,	+ 2	,,	= 6	,,
,,	16 = 4	,,	+ 0	,,	= 4	,,
					178	

Total 178 dents in the first half of the pattern, and an equal number in the second half. To these must be added 10 dents passed over in moving from the first to the second spot, and 22 dents in moving from the end of number 2 spot to the beginning of the first spot in the next repeat. Altogether, $178+178+10+22=388$ dents. To find the number of repeats of the pattern per yard of cloth -

$$\frac{40 \text{ picks per inch} \times 36'' \text{ per yard}}{64 \text{ picks per pattern}} = 22\tfrac{1}{2} \text{ patterns.}$$

$$\frac{388 \text{ dents per pattern} \times 23 \text{ needles per frame} \times 22\tfrac{1}{2} \text{ repeats per yard}}{20 \text{ dents per inch} \times 36'' \text{ per yard}} = \begin{matrix}278{\cdot}875 \text{ yards of whip} \\ \text{for one yard of cloth.}\end{matrix}$$

PART X

PICKING

PICKING is next in sequence to shedding, and consists in passing weft between the upper and lower lines of a divided warp. With few exceptions, the method adopted, during many centuries, and by weavers of all countries, was to throw a shuttle from one hand through a shed, and catch it with the other hand at the opposite side. But in 1733 John Kay, of Bury, invented the "fly shuttle." He constructed a box at each end of a slay for the reception of a shuttle, and employed two propellers, or "pickers," to move it. A box consisted of a bottom, two sides, and one end. Over each box was a metal spindle, about $\frac{3}{8}''$ diameter, for the purpose of guiding a picker. Both pickers were connected by cords to a picking handle, which the weaver grasped with his right hand, and by making a rapid lateral movement with his arm, the shuttle was driven with sufficient force to carry it across the warp and into the opposite box. Kay's invention was slow to find favour with weavers of his own time, but, when once adopted, it displaced the older method in most countries. The system of hand-thrown shuttles is still in operation in some countries, and strange to say the plan has been adopted by a number of people who are endeavouring to foster hand weaving in this country.

More recent inventors have mainly endeavoured to

adapt Kay's invention to steam-driven machinery. The mechanism for propelling a shuttle is still simple in construction, but it is the least satisfactory part of a loom. For more than a century efforts have been made to perfect the pick: large sums of money have been spent in developing so-called improvements, in safeguarding work-people, and in preventing breakages of machinery and warp; yet the pick remains uncertain in action, costly to keep in order, and more serious accidents result from its defective action than from all the remaining parts of a loom taken together.

Picking inventions include a varied collection of picking devices, of shuttle guards, swells, check straps, fast and loose reed appliances, pickers, and an endless variety of details connected with the placing of weft between the warp, many of which are the result of a misconception of the problem, for they attempt to deal with the effect instead of the cause.

To appreciate the defects developed by a negative propelling motion, attention must be directed to the shuttle, which is made from wood, pointed at both ends, and tipped with steel. It is hollowed out in the centre and provided with a hinged metal tongue, whose length approximates to that of the hollow part. Weft, in the form of a cop, upon a wooden pirn or a paper tube, is pressed upon the tongue, and retained there during the operation of weaving. But it can be drawn through an eye in the front of the shuttle as a continuous thread.

Until box-wood was almost exhausted, shuttles were generally made from this material, and some are still made from Persian and African box, which has a dense, compact grain, and approaches more nearly to ivory than any wood known. Woods of less density than box are more difficult to drive across a loom, but Cornel, or dog-wood, is largely

used; it is hard, heavy, and fine-grained. Persimmon, a dark-coloured wood with a hard and fairly close grain, is also in demand. Spanish oak, English apple, Moorland crab, Pear, Satin, Beech, Hawthorn, and Ash are also used, either compressed or uncompressed. In 1884 Messrs. T. Pickles and B. Blakey patented a process by which blocks of these and other woods are subjected to a pressure of from 450 tons to 2000 tons in order to render them suitable for shuttles. The routine of shuttle manufacture is: Cutting the wood into blocks that approximate to the size of a shuttle; seasoning, which, where artificial heat is not employed, requires from two to three years; squaring and bevelling the blocks to fit the race board and reed; grooving and drilling the sides, and ringing and tipping the ends; hollowing the inside, turning, pegging, eyeing, tonguing, and polishing. Shuttles vary greatly in size and shape, and numerous patents have been taken out for tongues and the methods of attaching them. At the present time a weaver usually sucks the weft through a shuttle eye. It is known that this practice is unhealthy and responsible for the spread of numerous diseases. In order to remove these dangers many patents have been, and are being, taken out for semi- and self-threading shuttles, but the shuttles in general use have not been greatly improved for many years.

The rapidity of motion in a shuttle, combined with an imperfect control, are the chief causes of serious defects in picking motions. But numerous forces tend to divert a shuttle from its proper course.

It is a law of mechanics that the energy possessed by a moving body varies in proportion to its weight and the square of its velocity. Since a shuttle leaves a line of weft behind each time it moves across a loom, a constant diminu-

tion of weight and energy occurs until a shuttle is empty, and any obstruction will be more liable to divert a light than a heavy one. Therefore, unless a spent shuttle is heavy enough to overcome every resistance and draw weft close to the selvage of a fabric, the risk of flying out will be great. When passing through a shuttle eye there is greater tension upon a coarse than upon a fine thread; for this reason the weight of a shuttle should bear a definite relation to the tension upon a thread. This means a heavier shuttle should be employed for a thick than for a thin weft.

The position of the centre of gravity in a shuttle, with relation to the direction of force employed to propel it, has an effect upon its motion. The centre of gravity has been defined as a point about which a body would balance when that body is turned in any direction; and further, if a body which is uncontrolled is subjected to a blow, it will move in a straight line and in the direction in which the blow is delivered, provided the line of force passes through the centre of gravity; but otherwise the body will not merely move as a whole, it will revolve.

Although a shuttle is not free to move in any direction, it moves at a high velocity without being positively controlled. It is therefore imperative that the force employed to move it, and the parts used as guides, shall minimise any tendency to rotate. Let it be assumed that a shuttle is a parallelogram, and that its centre of gravity is at the centre of the body, as in Fig. 168. If a force D passes through the centre of gravity C, and parallel to all sides of the rectangle A B, the movement will be straight without the aid of guides; but an obstruction, such as rough, knotty, or entangled warp, will be sufficient to set up a rotatory motion. If the line of force does not pass through the centre of gravity, then the distance between

the centre of gravity and the line of force represents the leverage which will produce rotation; see Fig. 169, where A, B represent two sides of a rectangle, C its centre of gravity, D the line of force, and C, E leverage.

Rotation can be checked by placing the reed and race board against those sides of the rectangle farthest from the line of force; for this reason many shuttle tips are placed

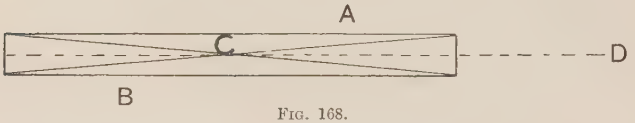


FIG. 168.

nearer the top and front than the back and base of a shuttle, for then the line of force will be above and before the centre of gravity. By so doing it is claimed that pressure will be exerted against the reed and the race board, and the tendency to fly up or outward will be checked; friction will thereby be slightly increased; but this is a small matter compared with the risks attending ejected shuttles. On the other hand, if the tips are too

FIG. 169.

high, they will pass over entangled warp and the shuttle will tend to move upward.

The centre of gravity in a shuttle does not occupy a fixed position, but is constantly changing. If when a shuttle is loaded with weft its centre of gravity is at the centre of its mass, every time it moves across the warp that point recedes in proportion to the weight of weft drawn away, because the weft is pulled from the forward

end of a cop. Hence, until the weft is half exhausted the front of a shuttle becomes lighter, while the back remains unaltered. The change is small, yet it helps to make the movement of a shuttle uncertain.

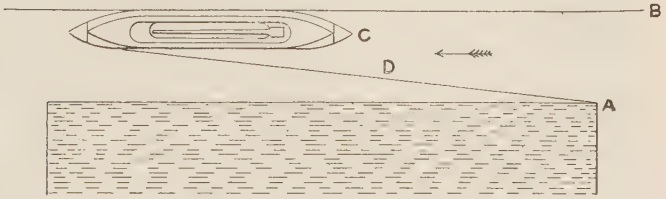


Fig. 170.

When weft is passing through a shuttle eye a side pull of varying intensity is exerted, which also tends to deflect a shuttle. A reference to Figs. 170 and 171 will illustrate this point. The arrows indicate the direction of motion: A is the cloth fell, B the reed against which the shuttle C moves, D is the weft running diagonally between C and A.

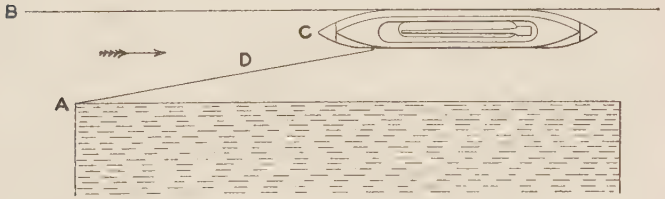


Fig. 171.

An obstruction to the free passage of weft through the shuttle eye will, in Fig. 170 draw the front of C from B, when C will be ejected from the loom. In Fig. 171 the forward end of C will be tilted against B, and this slightly reduces the risk of flying out, but the effect in either case

will be in direct proportion to the intensity of the pull. If the eye was placed at the centre of a shuttle, and the weft revolved as in ribbon shuttles, the pull would be equal in both directions.

Weft is less free to pass from a shuttle eye when a cop has nearly given out than when full; this is due to the shuttle eye and tongue retaining their relative positions, while the position of the weft upon the tongue varies. A thread passes from the outer surface of a full cop to the tip of a tongue at a great angle, but as it is withdrawn from the shuttle the angle is reduced and a coarsely pitched coil of thread begins to form; this puts additional tension upon it. As a result, the movement of a shuttle is modified in a twofold degree: first, by a reduction in weight, which results in a reduction of force; and secondly, by an increased diagonal pull being exerted when the shuttle is least capable of resisting it.

It has been previously stated that a shuttle is guided by the race board, upon which it rests, and the reed, against which it presses; both are parts of the slay, and swing about a centre by the action of cranks and connecting arms. It follows, therefore, that a shuttle partakes of this swinging motion in addition to that of translation.

Fig. 172 is a diagrammatic representation of the above-named parts: A is the shuttle, B the slay, C the reed, D a sword, E the rocking-shaft centre about which D moves; F is a connecting arm, G a crank, and H a dotted line showing the circular path of G. When a shuttle begins to move, the several parts occupy positions corresponding with the solid lines; the slay is moving back and continues so to move until the crank G reaches point 2 in the periphery of the circle H, where a slight pause takes place for reasons that are fully dealt with in Part XVI. The

position of each part at this instant is indicated by the same letter with the addition of a dash against dotted lines.

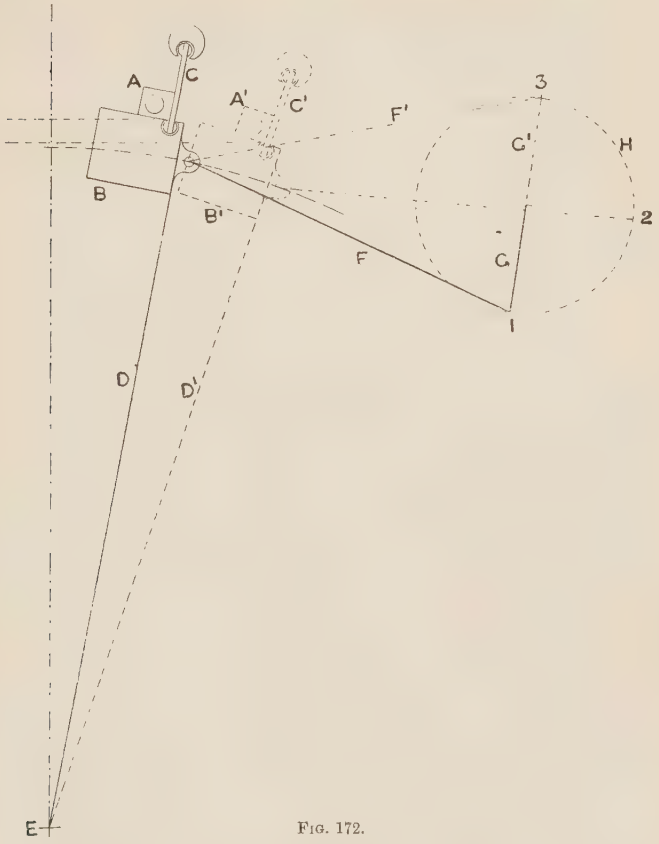


Fig. 172.

It will be noticed that when the sword is at D′, the shuttle A is in a lower plane than at D, the fall of the slay being indicated by the space between the lines 4, 5. In consequence of which, during the movement of

the slay from D to D′, the shuttle has been travelling across the loom, moving back, and falling with the slay ; but as the crank G moves round point 2, the shuttle simply continues to pass across the loom. Between points 2 3 the shuttle moves up and forward with the slay until it finally reaches the opposite shuttle box.

Fig. 173 will further elucidate the aggregate motion of

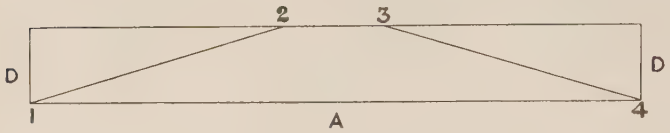


Fig. 173.

a shuttle. Let the line A represent the breadth of a loom, and D the backward movement of a slay ; it will then be found that a shuttle, in passing from 1 to 4, moves in a curved path, from 1 to 2, straight from 2 to 3, and in the opposite curve from 3 to 4. This does not reveal all its motions, for the fall and rise are not taken into account. In Fig. 174 A equals the width of a loom, and 1 5 and 4

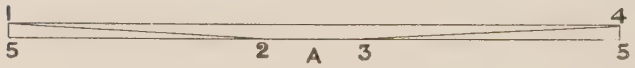


Fig. 174.

5 the fall of a slay. Hence the shuttle falls from 1 to 2, moves straight from 2 to 3, and rises from 3 to 4.

Add to these modifying influences that a shuttle begins its journey when a slay is moving back at nearly the same speed as a point in the periphery of the crank circle H, Fig. 172 ; but after the crank passes point 1 the velocity of the slay is rapidly reduced, until at 2 a pause is reached ; then from 2 to 3 the increase in velocity is proportional to

the decrease from 1 to 2; and it will be observed that a shuttle partakes of many variations in velocity and direction, yet they do not all necessarily tend to eject it from the loom. On the contrary, some of them assist in reducing such a tendency. For example, when a shuttle begins to move across, it is also travelling back with the slay at its greatest velocity, and if at such times the reed and box back were removed, the shuttle would continue to travel backward; but with the reed in position, as the slay's speed is reduced a shuttle presses against the reed with a force in proportion to its weight and acquired momentum, and this minimises its liability to fly out.

Many forces, therefore, are acting simultaneously or successively which tend to make the movement of a shuttle a complex one. Still, the mechanism for controlling it is less efficient than is generally supposed. Before proceeding to describe the varied devices used to propel a shuttle, it will be advisable to determine what features may be considered essential to a good pick, for if this is done the relative values of picking motions can then be more readily appraised. The following points are suggested as essentials:—

(1) The power consumed. When a shuttle is negatively driven, much energy is wasted, partly on account of the difficulty of accurately gauging the force required, and partly because all motors are liable to variations in speed. On entering a box the momentum of a shuttle must be destroyed or the shuttle will rebound. Therefore the first proposition is: that since the weight of a shuttle and the time taken to move it are of greatest moment, only sufficient force to pass that shuttle across a warp in the time allotted should be employed.

(2) Altering the speed of a loom. If the speed of a

loom varies, the energy of the picking mechanism varies also; an acceleration causes a shuttle to rebound through excessive force; and a retardation prevents a shuttle from reaching the opposite box owing to insufficient force; in either event the loom stops. A similar effect follows if two shuttles of unequal weight are used in a loom, for, if the pick is correctly set to the light shuttle, the heavy one will be driven with violence into the opposite box; but if the pick is set to the heavy shuttle, the light one will not reach its destination. This has long been one of the most obvious defects of negative driving, for numerous parts have been devised to prevent an alteration in the speed of a loom from affecting the picking force. The second proposition is that energy in the picking mechanism should remain constant, irrespective of fluctuations in the speed of a loom.

(3) A desirable motion. The movement of a negatively driven shuttle is essentially jerky, and frequently produces the most disastrous results; its velocity is developed suddenly, and is greatest as it enters the shed which at this instant is small, for the driving cranks are little beyond their bottom centres. As the reed moves back considerably more room will be provided for a shuttle to pass, and granting that obstructions are less likely to eject a shuttle as it enters a shed than elsewhere, there is a risk of breaking the warp. Again, the power required to develop a high speed suddenly is in excess of that required to develop it gradually. The third proposition is, therefore, that a shuttle should begin to move slowly, develop speed until it reaches the slay centre, and from the centre to the opposite side a corresponding decrease should take place.

(4) A positive motion. Most of the serious accidents

that occur in weaving sheds are caused by flying shuttles, and these are due to negative picking. In order to compass the movements named in the preceding paragraph a shuttle would of necessity be positively controlled, and this would mean safety to the work-people, a considerable reduction in power and breakages, as well as a cheapening of production. The fourth proposition is, therefore, that a shuttle should be under complete control throughout its movement, and that the loom and shuttle should be capable of starting and stopping together, whether the shuttle is in or out of the warp.

(5) Connecting the principal motions. In many looms shedding, picking, box, and taking up, and other motions work independently of each other, and it is the object of the fifth proposition to prevent this by positive connections which will prevent one piece of mechanism from getting out of sequence with the others.

The picking motions now in use do not fulfil the conditions set forth on the preceding pages, but a weaving student must consider whether a piece of mechanism which gives a blow to a shuttle and leaves it without sufficient control is either true in principle or economical. Also to what extent the application of guards, swells, check straps, and other parts designed to prevent shuttles from flying out are attempts to deal with the effect instead of the cause.

The mere enumeration of the requirements of a picking motion is sufficient to show that a formidable problem must be solved before a truly satisfactory pick can be obtained; and an analysis of the defects arising from inattention to the points mentioned will reveal the pressing need for improvement.

Attention has been frequently directed to this subject,

and various devices have from time to time been resorted to with a view to improvement. Fig. 175 illustrates an attempt made by Messrs. Butterworth and Dickinson to economise power by removing pressure from a shuttle as it leaves a box. A lever A is so secured upon the stop rod B that it may normally bear upon the swell C. A hook upon B holds the upper end of a spiral spring D, but its lower end is attached to the slay sword E. The spring, therefore, holds A in close contact with C, and a shuttle in entering a box must possess sufficient energy to overcome the resistance of D. The pressure of A C upon a shuttle as it leaves a box is relieved by a bent finger F attached to the rod B. As the slay moves back the free end of F passes beneath an antifriction bowl G mounted in a vertically adjustable bracket H, and G presses F down and A back at the moment of picking. At other times this device permits the spring D to act upon C with its full force. Another shuttle easing motion is illustrated in Fig. 238, where D is a stop rod shown bent backward at D′ to receive the swell lever E, which is set to bear upon the swell E′. A blade F is also secured upon D, and operated each time the slay recedes from the cloth by a rod I. The rear of I is held between the prongs of a supplementary, forked, connecting-rod K′ by a strip of metal P, but the forward end of I passes through a hole in a sword B. The rod I carries a spiral spring J′, one end of which impinges against the sword, the other against a stop hoop J. This spring normally thrusts the stop P′ upon the arm K′. As the crank H revolves, a projecting piece O′ on the connecting arm K makes contact with a bowl Q on the rear of I, contracts the spring J′, moves I against F with sufficient force to partially rotate D and remove E from the swell.

A cam has also been fixed upon each extremity of the driving shaft to cause two levers and links to release a shuttle before picking. In many American looms a swell is placed in front of a shuttle-box, and in some of them a flat spring is bolted to the breast beam, so that at the time

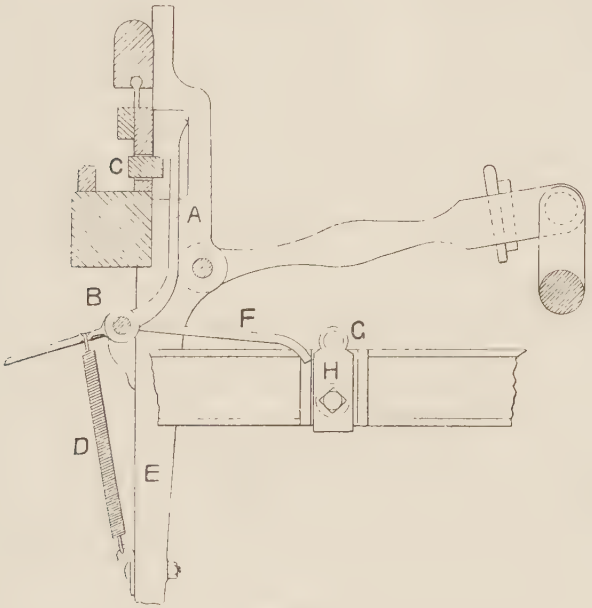


Fig. 175.

of picking a double cam surface formed beneath the spring may pull back the swell finger; at other times the spring bears upon the finger to check a shuttle as it enters a box. But such appliances as the foregoing cannot effect great economies in power. In most cases it is a question of reducing the power consumed by the pick and increasing that by the slay. They, however, materially reduce the

wear of pickers, strapping, picking noses, and other parts of a loom.

Shuttles have been moved by the elastic force of compressed air, by gravitation, by electricity, by a carriage, by a worm, by springs, by cams, and by other means; some of which have a negative, others a positive action. Negative or conditional picks are over, and under, alternate, and pick-at-will. The difference between an over and an under pick relates to the position of the picking arm fulcrum, which if entirely below the shuttle boxes constitutes an under-pick, but if some portion of the fulcrum is above the boxes the motion becomes an over-pick. Of under-picks there are *a*, those that deliver a blow from the bottom shaft, and *b*, those that deliver it from the crank shaft. In most of the motions included in division *a* it is possible to cause the piece that receives the impact to push rather than strike a shuttle, and when this is accomplished the best results are obtained. It must, however, be admitted that less attention has been given to this matter than it deserves, and as a consequence, if under-picks are compared with over-picks, it will be found that the former usually consume more power, work less smoothly, and the number of shuttles ejected is greater than in the latter.

Pick-at-will motions are applied to looms that have multiple boxes at each end of a slay; they permit two or more shuttles to be driven from one end of a loom before a return movement is made from the opposite end. A single weft thread of any colour may thus be passed through a warp; this is rarely attempted with alternate picking. Most of the pick-at-will motions are modifications of alternate picks, and the mechanism can be converted from one system to the other without making

important structural changes, but some alternate picks require considerable modifications and additions to adapt them for pick-at-will work.

Over-Picks

A few years ago several types of over-picks were commonly met with, which have now become obsolete, and it may be affirmed that, with the exception of one type, over-picking is not progressing. In England, however, the cone over-pick is attached to more looms than all other systems and varieties of picking taken together.

The cone pick is used for most fast-running looms weaving light and medium fabrics; and for many both narrow and wide looms weaving heavy fabrics. The mechanism has also been modified to suit pick-at-will looms. It consists of a vertical shaft A, Fig. 176, which is placed either inside or outside the loom framing, but when placed outside it gives the most satisfactory results, for in that position a picking tappet can be moved near its bearing, and greater steadiness obtained. Shaft A serves as the fulcrum of a lever; it is held against the loom framing by a cannon bearing near the top, and a footstep at the base. This footstep is bolted to the loom framing, and no provision was made for vertically adjusting the shaft A, until T. Pickles, in 1904, passed a set-screw, with a cone-shaped tip, through the base of the footstep, and formed an internal cone at the foot of A. When once adjusted a lock-nut on the set-screw made all secure. One arm of A consists of a short stud B that carries a loosely fitting, truncated cone. B is either passed through a slot in A and secured by screw and nut, or it occupies a fixed position upon A. The long arm C is of wood, and attached

to a ring on the top of A having radiating teeth on its upper surface for a ring with similar teeth on the under side to fit into. These teeth form a rigid connection and facilitate adjustment. A grooved cap is bolted over the

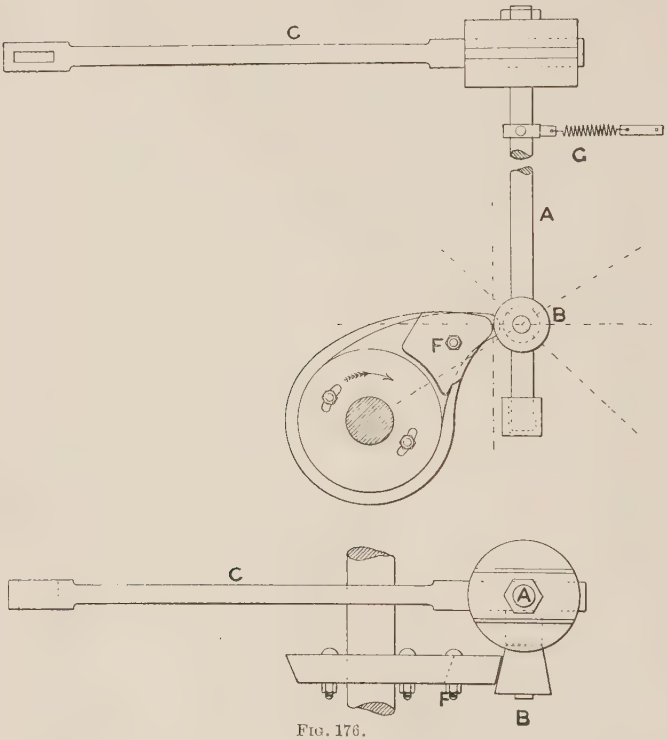


FIG. 176.

picking arm C to hold all secure. From the forward end of C a leather strap passes down to a buffalo-hide picker which is freely mounted upon a spindle placed over the shuttle-box centre.

A tappet is keyed upon the bottom shaft and inside the

framing, in revolving, its nose F strikes the cone-shaped antifriction roller on B; partly rotates the shaft A and the arm C, and causes the picker to move inward with sufficient velocity to drive a shuttle across a loom. The tappet F is made in three parts: one consists of a fixed disc, which is keyed upon the bottom shaft. Another part is provided with a smooth oblique surface, and with concentric slots for bolts to pass through; the slots permit of a slight adjustment to vary the time of picking. When a greater change is needed than the slots provide for, the driving wheels must be disconnected and the picking shaft turned forward or backward before again putting the wheels in gear. A groove is also formed to take the third piece—namely, the picking nose.

Similar mechanism is fitted at both sides of a loom, but the picking tappets F oppose each other; for when the noses of both pieces F are in a vertical plane, one is above, the other below, the shaft centre.

The conical roller on B is kept in contact with the tappet F by attaching one end of a spiral spring G to any convenient part of the framing, and the other end to a hoop upon A. This hoop is usually fixed immediately below a bead on the framing in order to prevent the shaft A from moving vertically. The spring G also causes the picking arm C and the picker to move back after the delivery of each pick. On narrow looms the straps from both shafts A are connected to opposite ends of a spiral G, situated below the warp; then, as a pick is delivered at one side, the power required to distend G is utilised in pulling back the free arm C. Since a picking strap is more or less slack when an arm C is in a state of rest, it follows that a picker can only be partially drawn back by C; but its backward traverse is completed by a shuttle impinging against it.

The high speeds attained by many looms using this pick have rendered careful construction of the tappet F essential, and easier working, a smaller consumption of power, and reduced wear and tear have resulted. Yet the cone pick will remain defective, so long as energy is developed from a slow-running shaft, in from $\frac{1}{9}$ to $\frac{1}{18}$ of its revolution. At $\frac{1}{12}$ of a revolution a picker in a loom making 200 picks a minute completes its journey in about $\frac{1}{1200}$ part of a minute; but its velocity is not uniform, for a tappet pushes a cone stud, in equal units of time, through evenly accelerating spaces in the proportion of 1, 3, 5, 7, 9.

It is difficult to obtain the exact amount of power required to drive a shuttle, for the conditions under which it performs its office vary. There are differences in friction, caused by large and small sheds, rough and smooth, close and open warps, strong and weak swells, also differences in the weight of a shuttle; but the energy can be approximately reached as follows:—

The work accumulated $= \frac{wv^2}{2g}$, where w equals the weight of a shuttle in pounds, v its velocity in feet per second, and g 32·2.

For example, assume a loom to make 200 picks per minute, and that a shuttle weighing 10 oz. is moved across a space of 5 feet in $\frac{3}{8}$ of a pick; then the average speed of such a shuttle is $\frac{200 \times 8 \times 5}{60 \times 3} = 44{\cdot}4$ feet per second, and the energy developed is $\frac{10 \times 44{\cdot}4 \times 44{\cdot}4}{16 \times 2 \times 32{\cdot}2} = 19{\cdot}13$ foot lbs. per pick, or $\frac{19{\cdot}13 \times 200}{33{,}000} = 0{\cdot}116$ of one horse-power.

The length of a picking arm C, Fig. 176, is to some extent determined by the reed space of a loom, as the latter should not exceed C by more than $2\frac{1}{4}$ times; on an average, a 20″ arm is used with a 45″ shuttle race. The length of a picking arm fixes the position of the upright shaft A, because, when the reed and fabric are in contact, the arm C, if moved half the length of the picking spindle, should place the centre of the picking strap, where it leaves the arm, in the same vertical plane as the spindle centre.

Energy is often wasted by giving the picking force an upward or a downward direction; but if, as far as circumstances will permit, this force is transmitted to the cone stud B, at an angle approximating to a right angle, much of the harshness of this pick disappears.

Since a cone moves horizontally in the arc of a circle, its surface will form different angles with the tappet shaft, and also with the picking tappet F; hence the latter must be bevelled to present a flat surface to the cone in every position. This bevel has rendered the correct construction of such tappets difficult of attainment. It has been customary to fix a roughly shaped wooden model in position upon the tappet shaft and, by rotating it slowly, to note if sharp edges were presented to the cone, and if so, to alter the shape where necessary; after which a casting was made from the model.

A picker may move 7″ to 14″ at each stroke of a picking arm, but it is only driven through 6″ to 11″ by a tappet F; the inertia completes its movement and is of no consequence to the shuttle, because the latter leaves the picker so soon as a decrease in speed takes place, A picking tappet may be said to have three functions, namely, to tighten the picking band, to drive a shuttle through the warp, and to reduce the momentum of both picking arm

and picker. A tappet gradually tightens the picking strap to avoid giving a jerk to a shuttle; during this time the arm C, and the stud B, move through an angle approaching 10 degrees. This is followed by picking the shuttle across, and from 20 to 30 degrees of accelerating movement in C, B is usually allowed for the purpose. Lastly, a further movement is given to C, B, in order to bring them gradually to a state of rest and thus reduce the wear and tear—say $7\frac{1}{2}$ to 10 degrees in the decreasing ratio of 3, 2, 1.

It has been asserted that a shuttle is intended to be in the middle of a slay when the driving cranks are on their back centres, but in practice this is not adhered to. Much depends upon the time and force of picking. A pick is set to act between 15 degrees before the bottom centres are reached, and 10 degrees after they are passed. If, for example, a shuttle begins to move when the cranks are 10 degrees past their bottom centres, and makes its journey in $\frac{3}{8}$ of a pick: $\frac{3}{8}$ of $360° = 135°$, therefore, when the cranks are on their back centres the shuttle should be past the middle of the slay, for $135° - 80°$ leave only $55°$ of movement in the cranks in which to complete its course.

If a pick is set earlier a shuttle will, with an equal driving force, be considerably beyond the slay centre when the cranks are on their back centres.

Fig. 177 shows the construction of a picking tappet: A is the bottom shaft, B the picking tappet, C a sectional view of the upright shaft, which is assumed to be $6\frac{1}{2}''$ from the centre of A to the centre of C; D is the cone, and E the horizontal plane in which D moves when the tappet nose F is pressing upon it. Solid lines show the cone stud and bowl in contact with the shell of B, and dotted lines show them after they have been moved, by the nose F, 30 degrees. The tappet disc is employed to tighten the picking strap,

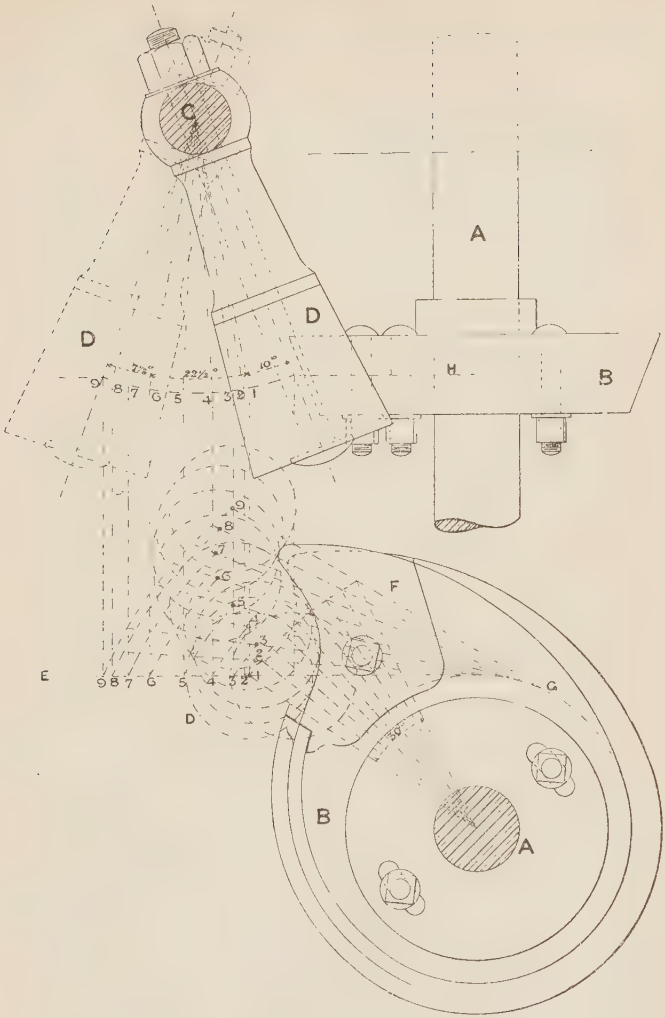


Fig. 177.

but in practice tightening begins between the top and front centres of the driving cranks. In some looms upwards of 100 degrees of movement are allowed; this shows that the time taken is unimportant. The actual delivery of the pick is therefore the starting-point. Divide $22\frac{1}{2}$ degrees of movement in the cone D into 25 parts, and, reading from right to left, drop perpendicular lines through intersecting points, 1, 2, 5, 10, 17, and 26, which will give the proportions of 1, 3, 5, 7, 9. Divide the remaining $7\frac{1}{2}$ degrees into six parts, and drop perpendicular lines through points 4, 6, 7, which will give the proportions of 3, 2, 1. Describe, from the centre of A, a circle G, equal in radius to the vertical distance between the centre of the cone stud and the centre of the tappet, say 3″, and draw a horizontal line E tangential to G. The perpendicular lines 1 to 9 cut E at right angles. Draw a line radiating from A to pass through point 1 on E. From A, 1, make an angle of 30 degrees, and divide it into eight equal parts. Through each point where a radial line intersects the arc line draw a line tangential to the circle G. Then with radia A, 1 to A, 9 describe arcs in rotation that cut the tangential lines. Let each point of intersection represent the centre of the cone D as it is pushed outward by the tappet. Describe a circle round each having a diameter equal to that of D, where it touches the line H on the tappet B. To find the centre line of the nose F, trace a line that touches the periphery of each circle. The inner and outer edges of F can be obtained in a similar manner, but the diameter of the cone D must be taken where contact is made with that portion of the tappet face to be drawn.

The line already traced is slightly inaccurate, owing to the circles that represent the cone being uniform in diameter, instead of having diameters that differ in accord-

ance with the varying points of contact between the cone and the tappet; and, again, only one true circle could thus be obtained, namely, when the cone stud and tappet shaft were parallel; at all other places elliptical figures should have been described. But the plan followed has been adopted to avoid undue complication, also because the inaccuracy is so slight as to be of no practical account. Still, if it is thought desirable to construct a geometrically

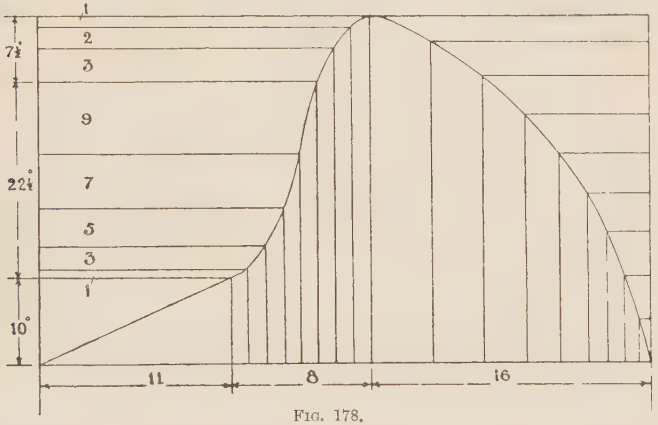


Fig. 178.

correct tappet, take the dimensions of the cone D at each of the eight defined points, and draw ellipses of the proper shapes instead of circles.

Fig. 178 represents the movement of a cone stud as traced from a picking cam fitted upon a 45″ reed space calico loom. The thick line shows how the stud is moved from the time of tightening a picking band until it again becomes motionless. The movement made to drive a shuttle equals 40°; for the first 10° of which the stud is pushed from the bottom shaft uniformly. For the following 22½° it moves in equal units of time through accelerating spaces,

represented by 1, 3, 5, 7, 9. For the remaining $7\frac{1}{2}°$ it moves through decreasing spaces, represented by 3, 2, 1. At the end of the last-named position the cone is upon the extreme point of the cam, and from thence it is gradually restored to the disc.

The time taken to make the entire outward and inward journey equals 260° of movement in the driving cranks, namely, 80° for tightening the picking band, 60° for delivering the blow, and 120° for moving the stud back, leaving 460° for the stationary period.

An idea prevails that a shuttle is less liable to fly out if a box spindle is slightly tilted upward and outward at the inner end, and if a fall is given to a race board, between the shuttle box and the centre of the reed space, of about $\frac{3}{32}''$ in a 45″ loom. Some loom-makers also give a reed an outward bow to the extent of $\frac{3}{32}''$ on the above-named width of loom. The reasons assigned are that a picker in travelling along an inclined spindle elevates the rear end of a shuttle and tilts its forward end nearer the race board and reed. By so doing any tendency to rise is minimised. Also that a sloping race board and a curved reed assist in further reducing the chances of flying out by permitting the shuttle to continue moving in a downward and backward direction to the centre of the reed space, by which time much of its energy will be expended.

Advocates of this plan point to under-picked looms as demonstrating its utility, for in those picks the curvilinear movement of the picking arm, when near the front of a box, has a tendency to press down the rear end of a shuttle, and impart an upward direction to the forward end. As most of these looms are more liable to eject shuttles than over-picks, the plea seems to be a reasonable one. Still, the difference is doubtless due in part to the

more rapidly developed force in many under-picks. Until exhaustive experiments have been made, the question must remain a more or less speculative one.

When a cone over-pick is converted into a pick-at-will motion, the picking tappets may be made to slide out of reach of the conical bowls, or each bowl stud may have a swivelling joint, by which a bowl can be lifted out of contact with a tappet. Or, again, a clutch on the upright shaft may be opened to avoid picking, and closed to pick.

Under-Picks

The cone pick has been converted into one of the best motions for alternate under-picking, and has been applied with great success by Continental makers of silk looms, producing a much smoother pick than is usually found on under-pick looms. It has also been adapted for under-picked, pick-at-will looms. For the latter purpose a novel feature has been introduced, namely, that of causing a shuttle to decide from which end of a loom the following pick shall be delivered. Further, if through faulty manipulation two shuttles face each other, neither will be ejected from its box. The last-named feature is a desideratum in all pick-at-will looms, for much breakage of warp, and many smashes of other kinds, result from one shuttle being driven out of a box when another is in the opposite box.

The parts are as follows:—The picking cams F, Fig. 179, are doubled-nosed; in other respects they are similar to those of an ordinary cone over-pick, but the shaft A, together with its short arm, and cone B, are fixed horizontally outside the framework, so that B is beneath F. The wooden picking stick has been replaced by a short metal arm C, which terminates in a catch. A second arm

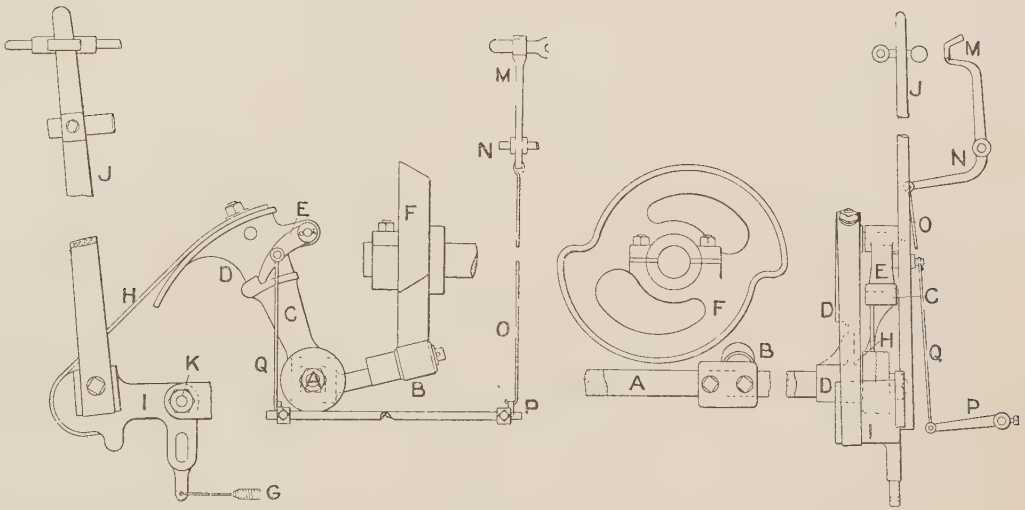


FIG. 179.

D is loosely mounted upon A, and carries an adjustable fulcrum pin for a latch E to vibrate upon. A strap H, bolted on the curved upper surface of D, is led round a curved portion of a shoe I. This shoe is a three-armed lever; its long arm J is furnished with a picker that is loose upon a spindle placed parallel with a shuttle box. The horizontal arm of I is drilled to receive a fulcrum stud K on the rocking shaft, and to it the strap H, and the picking arm J, are secured. The vertical arm of I sinks below K to take a spiral spring G, by which J is drawn back to the outer end of a shuttle box. Provided both latch and catch engage, as C is vibrated by the stroke of F, the strap H is tightened, tilts over the arm J, and drives a shuttle through the warp. As I moves about its fulcrum pin, J rises and falls in addition to moving to and fro. Although this does not produce a parallel motion at the picker level, yet the stroke more closely approximates to a parallel one than is usual in under-picked looms.

A latch E is lifted above the catch on C when its picking arm J is to remain in a state of rest. This is accomplished by mounting a cranked lever M freely upon the stop rod N, so that its vertical arm shall rest against a box swell. To the horizontal arm of M a wire connection O is made with a lever P, whose fulcrum is a light rod that crosses the loom in front of the rocking shaft. From the opposite end of this rod the second arm of P is united by a link Q to the latch E. Whenever a shuttle in a box faces a picker, the finger M is pressed back by a swell, it vibrates P, and moves E out of contact with C, thereby permitting J to remain stationary while C moves. Similar parts are fixed on both sides of the loom, hence, if a shuttle in a right-hand box faces its picker, the latch E on the left hand will be lifted and that picking arm will remain

inoperative. Likewise, if a shuttle in the left-hand box faces its picker, a latch E on the right hand will be lifted and that picking arm be thrown out of action. Also, if

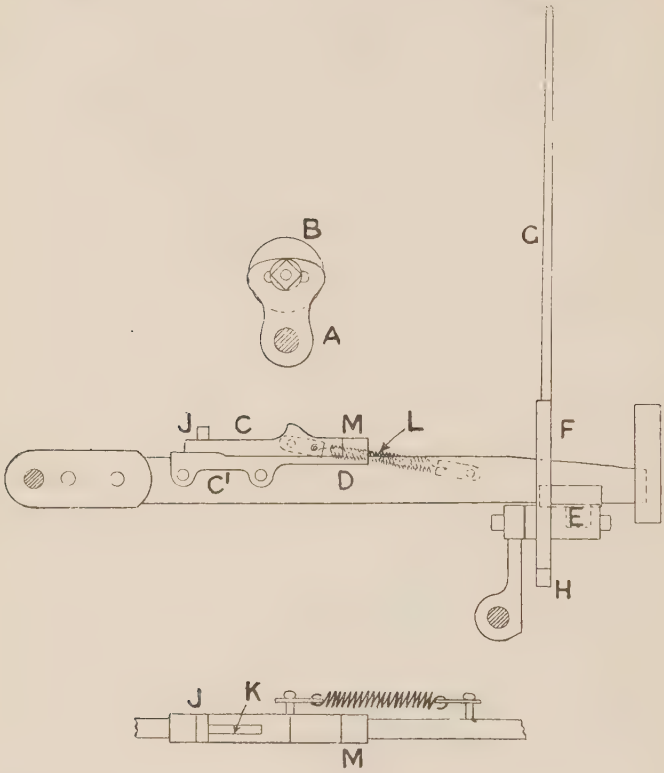


FIG. 180.

two shuttles face the pickers, both picking arms will remain stationary.

The lever pick is one of the best known under motions; it consists in fastening an arm A, Figs. 180, 181, upon the

bottom shaft to carry an adjustable stud and bowl B. As A revolves towards the left, the bowl B strikes a curved metal plate C, which is bolted to a wooden lever D, the latter being fulcrumed upon the rear of the end framing. The forward end of D rests upon a short arm E, of the picking lever F, G. The fulcrum pin of E, F, G is fixed in a bracket on the rocking shaft and swings with the slay. G is a wooden arm which passes through a slot in the base of the shuttle box; a leather picker is dropped over its upper end, and a wooden or iron rib at the back of the shuttle box holds the picker in position.

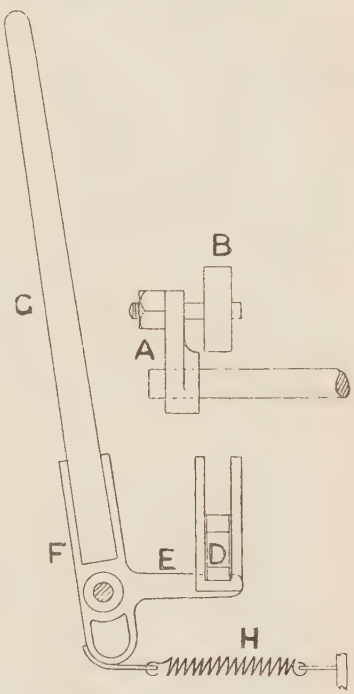


Fig. 181.

When a bowl B strikes the picking plate C, it depresses the lever D, tilts the picking arm and picker, and drives a shuttle across the loom. A spring and strap H draw the arm G back to its normal position.

Duplicate parts are placed at the opposite end of the loom to return a shuttle, but when one pick is active the other is inoperative. Since a picking arm of the foregoing description vibrates about a centre, it rises and falls in the picker, and this causes the arm to abrade rapidly;

also, in moving to the vertical position, it tilts up the rear of a picker; but in moving from the vertical position to the inner end of its stroke, the front of a picker is tilted up. All these movements are undesirable, and can be prevented in various ways. A plan known as "Stearns parallel motion" has a stand A, Fig. 182, fixed upon the rocking shaft, and A has a uniformly flat surface, except for a vertical projection B and a slot. A wooden plug saturated with oil is driven into the inner end of a slot in A to serve as a fulcrum for a picking arm C. This arm C is bolted upon a shoe D whose under surface is cam-shaped, and the cam rests upon the stand. A hole in the shoe receives the projection B, and a curved tongue E is bolted upon the picking arm. E and the base of C pass through the slotted stand A. An arm C is pulled outward by a strap F and a spiral spring G. The strap F is hooked into the base of the tongue, and also attached to a pulley, which is loosely mounted upon a stud in the stand. One end of the spring G is rigidly fixed to a projection on A, the other end is passed through the periphery of the pulley and through the strap F.

As a picker C advances to eject a shuttle from a box, the curved face of D lowers C sufficiently to enable a picker, when screwed upon C, to move in a plane parallel with the box bottom. In making this movement the base of C tightens the strap F and partially rotates the pulley; this puts a twisting strain upon the spring G, and the energy so created draws back both arm and picker to their normal positions, when no longer under the influence of a picking cam.

If a slay has two or more shuttle boxes at one end or at both ends, the picking arm G, Figs. 180, 181, passes through a slot in front of the boxes, and also through a buffalo-hide

picker which slides upon a guide spindle. A further alteration has been made in one or both picking plates C, in order to avoid ejecting shuttles from the boxes when a slay is moved backward. It consists in fixing a casting

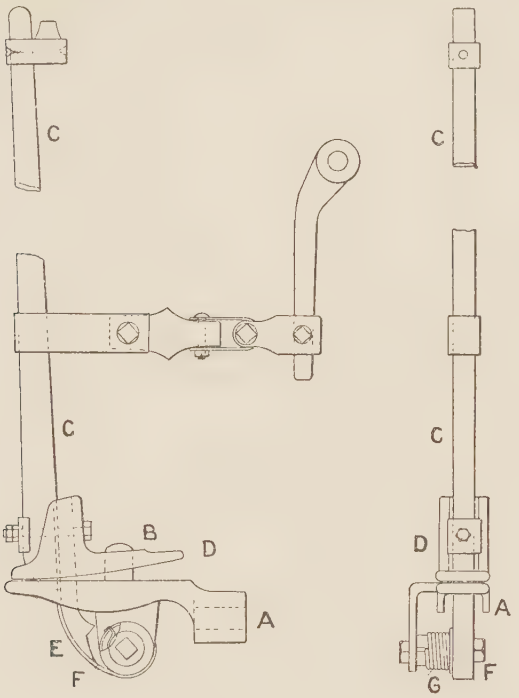


FIG. 182.

C′, Fig. 180, upon D, for the reception of a sliding picking plate C, and in securing C to C′ by passing a bolt J through a slot K in C. When a loom is running in its normal direction, the plate C is drawn by a helical spring L against a fixed shoulder M, and a pick is

delivered in the usual manner; but when a loom is reversed, the bowl B strikes the back of C, distends the spring L, and causes the plate C to slide along the surface of C′ without depressing D, and consequently without moving either picking arm or shuttle. In case of obstruction to the movement of a shuttle, such as a box being lifted half-way, a picking arm is sometimes prevented from moving at all, at other times its fulcrum gives way and an arm moves at the lower instead of at the upper end.

In order to shape the plate C correctly, it is necessary to ascertain (*a*) the movement to be given to a picker; (*b*) the lengths of the two arms F, G, and E, Fig. 181, from the fulcrum to a picker centre, and from the fulcrum to the outer edge of D; (*c*) the dimensions of the lever D, between its fulcrum and the curved surface of C, and its fulcrum and the point of connection with E; (*d*) the radius of a circle described by the centre of a bowl B, and (*e*) the radius of a bowl B. Thus: assume a picker to move 9″; the mean length of F, G, from the fulcrum to the centre of a picker, to be 28·25″, and that of E, 4·75″; the length of D, from its fulcrum to its point of contact with E, to be 29″, and from its fulcrum to the point of contact with B, 16·25″. Then, 28·25 : 4·75 : : 9 : 1·513″ = the fall of E, where it touches D; and 29 : 16·25 : : 1·513 : 0·848″ = the fall of D, where it touches B. Further, let it be assumed that the centre of a bowl B, describes a circle 4″ in radius, and the bowl has a radius of 1·625″. The distance between the centre of the picking shaft A and the centre of the fulcrum pin of D, when measured horizontally, is 15″. The time for delivering a blow varies from $\frac{1}{13}$ to $\frac{1}{20}$ of a revolution of the picking shaft, but let $\frac{1}{16}$ be taken. The thickness and length of the picking plate C, is 1″ by 6″; and the depth of the lever D, $2\frac{3}{4}$″. The space through which

the lever D is depressed at its point of contact with a bowl is seen to be 0·848″. The ratio of depression is in arithmetical progression, or 1, 2, 3, 4 units of space in equal units of time, because a lever should begin to move slowly, and increase rapidly in velocity until a pick is developed.

In order to construct a picking plate, fix the position of the shaft centre A, Fig. 183, and describe a circle 1 with a radius of 4 inches; this will trace the path of the bowl centre. Drop a vertical line 2, 3, and from 3 divide the circle 1 into sixteen equal parts. Next divide the section 3, 4, which is $\frac{1}{16}$ of a revolution, into four equal parts. Round point 4 describe a bowl circle B, with a radius of $1\frac{5}{8}$ inches; draw the upper line 5 of the picking plate C at right angles to line 2, 3, and touching the periphery of the circle B. Show the thickness of the plate by drawing a second line 1 inch below and parallel with 5. Find the pin centre x by continuing the line 2, 3, downwards to 3′ and producing a line at right angles to it,

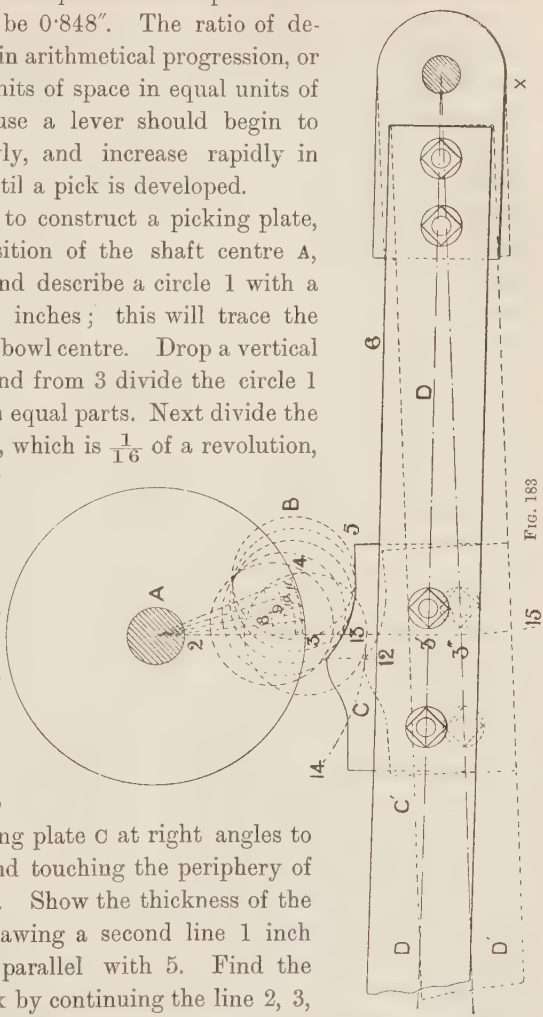


Fig. 183

at half the depth of D below line 6, $= 2\frac{3}{4} \div 2 = 1\frac{3}{8}$ inches, which gives the centre line of D when the lever is horizontal. On the centre line mark off 15 inches to the right, which equals X, and 14 inches to the left will give the point of contact of D with E (Fig. 181). Complete the lever D. With X, 3 as radius, describe arc 8, and from the same centre, through each point between 3, 4 formed by a radial line intersecting the circle 1, describe arcs 9, 10, 11. From point 3 on arc 8 cut 0·848 inch to equal the fall of the lever D, and divide it into ten equal parts ; then, with A as centre, describe concentric arcs through divisions 1, 3, 6, 10 to give the requisite ratio of depression. Begin with 4 and take in succession, as the centre of the bowl B, each point where the arcs, concentric with A, cut the arcs 11, 10, 9, 8, and describe corresponding circles. Trace a line touching the periphery of each, and the correct curve for C will be obtained. To define the length of this curve, fix the position of D when fully depressed, namely, 0·848 of an inch below the centre line at 3′. With a radius X, 3′ describe an arc ; from 3′ mark upon the arc 0·848 inch at 3″, and draw the lever D′ and the picking plate C′, as shown by dotted lines. Round point 3 in circle 1 describe a circle 13, and with a radius A, 13 describe an arc 14 which shall trace the periphery of the rotating bowl B. The nose of the picking plate C′ will be found where its curve is cut by arc 14. From 3″ measure the distance to the nose C′, and from point 3′, with the same measurement, cut the line 5 ; this will give the tip of the nose of C. Drop a perpendicular 12 through the nose of C, draw any curve on the opposite side, and make the plate C 6 inches long by taking 3 inches on each side of 12, and the picking plate is complete.

The lever pick is much used as a pick-at-will motion for

silk weaving, because it is clean, simple, easily altered, and capable of throwing shuttles in any desired sequence.

Figs. 184, 185, and 186 give respectively a plan, a front and a back elevation of this device. Two arms are keyed upon each end of the bottom shaft, and each is furnished with a bowl that can be made to strike or miss one of the picking plates C any number of times in succession. The

FIG. 184.

plates C are pivoted upon the picking levers A at N, and the rear end of each is so connected to a bar O that one is always parallel with A, while the other is moved out of contact with a bowl.

The mechanism for governing the picking plates C may consist in set-screwing a slide wheel P, Figs. 185, 186, upon the bottom shaft; on one side of P are two semi-circular flanges, and midway between the ends of these flanges two studs are fixed to make contact with an eight-sided star wheel Q. The pins in P partially rotate the star wheel Q upon a stud placed inside the framing.

The star wheel is compounded with a barrel whose office is to rotate a chain R, one link for every pick. The chain

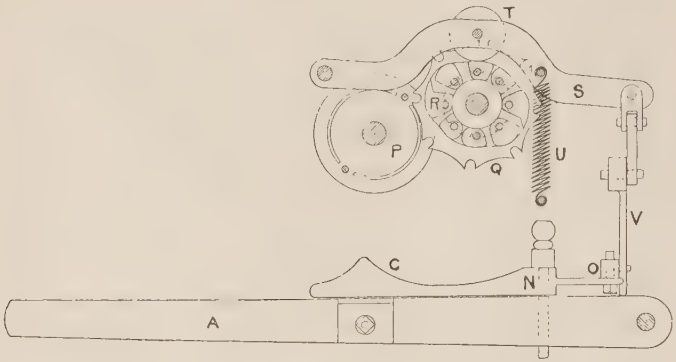


Fig. 185.

is built up of deep and shallow links to suit the required order of picking.

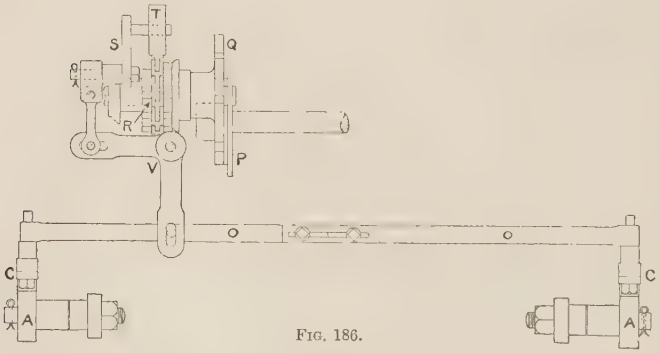


Fig. 186.

A lever S, also centred inside the framing, carries a bowl T, which is pulled upon the chain R by a spiral spring U, but rises or falls as the link beneath it is deep or shallow.

A cranked lever V is fulcrumed upon the back rail, and is connected by a link to the lever S. A stud in the bar O, Figs. 184, 185, 186, takes into a slot in the vertical arm of V and imparts a lateral movement to O whenever V is vibrated by the chain. Every movement of O pushes one picking plate C out of striking position, and pulls the other plate under a bowl.

Instead of controlling the picking plates C by a chain R, they may be actuated from a Jacquard machine as shown in Fig. 187, where the upper drawing is an elevation, and the lower one a plan of the parts:—A split, elliptical cam W is attached to the bottom shaft, and a bracket X is bolted inside the end framework. Upon X a brass slide Y is moved back horizontally every pick by the rotating cam W. Two spiral springs Z are fastened to Y and X, for the purpose of drawing the slide forward immediately it is liberated by the cam. A tongue 1 is hinged at 2 to the upper arm of a lever 3, whose fulcrum is at 4. The lower arm of 3 enters a slot in a cranked lever V, the latter being fixed upon the rear rail with both arms horizontal, and a finger 5, bolted upon the bar O, passes through a slot in the outer arm of V. A cord is passed through an eye formed in the tongue 1, at 6, and led to a spare hook in the Jacquard. A spiral spring 7, attached to the under side of 1 and also to the bracket X, draws the tongue into position for being operated by the slide.

When 1 is lifted the slide Y passes beneath it without producing any change, but when 1 is left down the slide thrusts it back, rocks the levers 3 and V, traverses the bar O laterally, places one picking plate C over a wooden arm A, and moves the other away from a second arm A, as seen in Fig. 179. This plan offers great scope for variety

of wefting, because the picking scheme need only repeat with one repeat of the pattern cards. Whereas the former plan is limited by the length of a chain R.

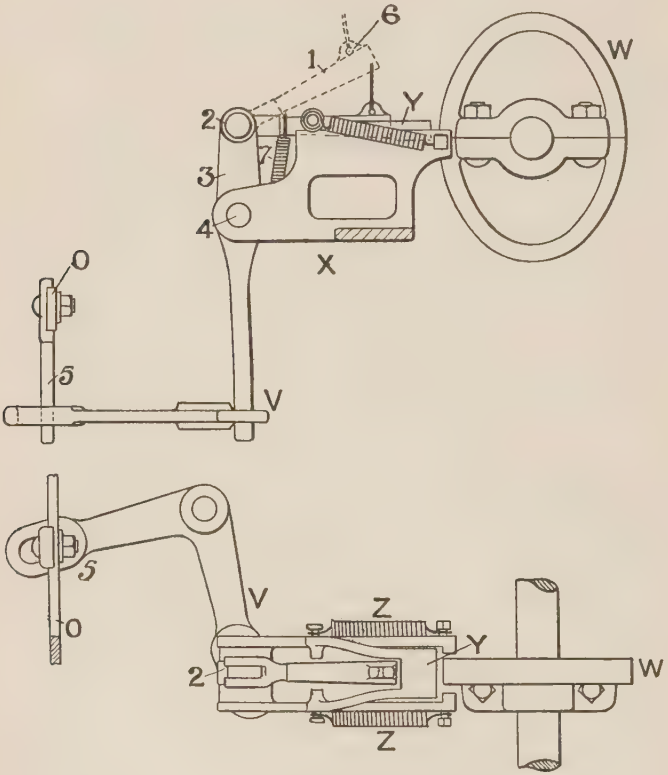


FIG. 187.

Figs. 188, 189 show Jackson's pick in plan and elevation respectively. This mechanism derives its movements from the bottom shaft A by means of an arm B, which has

an antifriction roller C mounted upon its outer end. By the rotation of A, the bowl C makes contact with the under side of an arm D. The arm D is keyed upon a

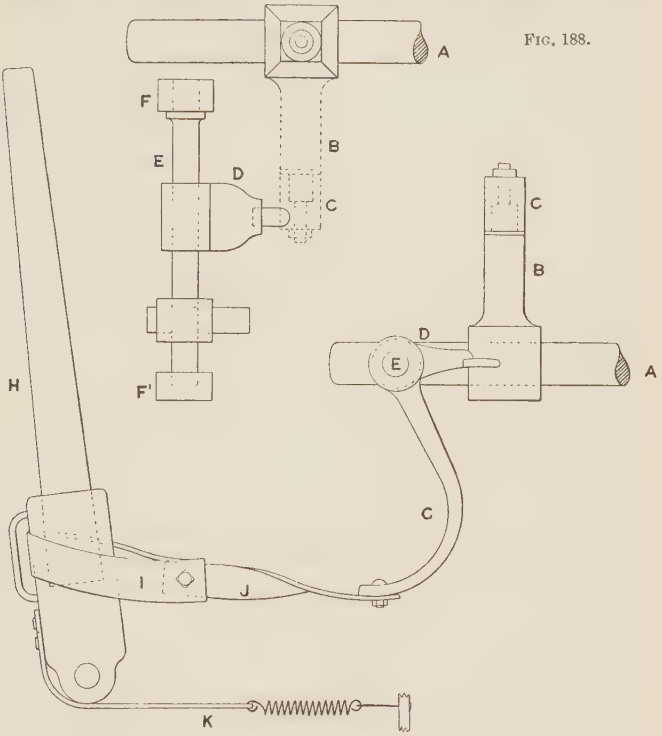


FIG. 188.

FIG. 189.

short shaft E, and E is held in the same horizontal plane as the shaft A by brackets F, F'. The shaft E forms a fulcrum for the lever D, G; the long arm G is curved and connected with the picking arm H by bending a strap I round the shoe of H, and bolting a second strap J to both I and G.

As the bowl C pushes up the arm D, the shaft E partly revolves; in so doing the arm G tightens the straps J, I, pulls the picking arm H inward, and drives a shuttle through the warp. A spring and strap K are employed to draw back the arm after each movement. It will be observed that if a loom furnished with this pick be run in the opposite direction, contact between C, D will slacken the straps I, J, and a shuttle will remain undisturbed.

Jackson's pick is used on pick-at-will looms, but a double striker B is provided at each side instead of a single one; and a lateral motion is given to the short shafts E by box tappets and lever connections. Lateral motion in E takes the arms D out of reach of the strikers B, C, and when moved the shafts may retain their positions for any number of picks.

Both flat and coiled springs have been connected by their forward ends to picking arms. Flat springs were alternately lifted, and coiled springs alternately compressed, by cams, then suddenly liberated at the proper moment to pick. Although these contrivances are not extensively used, they develop power gradually, and maintain a fixed energy in the picker for all speeds of a loom.

Picking from the Crank Shaft

In order to utilise the superior energy stored in a crank shaft instead of the inferior energy stored in a bottom shaft, Smith Brothers in 1834 introduced the principle of picking from a crank shaft. But a pick delivered from a crank shaft is comparatively harsh, owing to the short time during which a striker acts upon a receiver and to the difficulty of correctly shaping either a striker or a receiver.

If, while a picker is lightly pressed against a box end, one of these looms is slowly moved, it will be found that in some cases a picker is only moved by a striker about $\frac{1}{3}$ the length of a shuttle box. Whereas a similar experiment made with a cone pick will show that a picker is moved by the striker fully $\frac{2}{3}$ the length of a shuttle box.

One application of this principle was patented by Mark Smith in 1855. It is known as the "carpet pick," and Figs. 190, 191 illustrate it in front and side elevations. A is a portion of a crank shaft, B a fly-wheel, and C a striker bolted upon B. An inclined shaft E is placed outside the end framing; it is supported in a footstep F and by an upper bearing G. The shaft E carries a short arm D, a collar H, and a curved arm I; the latter is connected to the picking arm K by passing a strap J round a shoe in the usual manner.

An axial movement is given to the shaft E by a box tappet L, which is keyed upon the bottom shaft. A bowl O, mounted upon a stud in a lever M, works in the tappet groove, and as the tappet rotates, the lever M oscillates on a pin N. A fork formed on M at the opposite extremity to N impinges against the collar H, and either lifts E or leaves it in its normal position. If the former, the arm D is higher than the striker C, and the picking arm K remains inoperative; if the latter, D and C are brought together, and a pick is delivered. By altering the form of the tappet L and rotating it at a suitable speed, two or more shuttles may be driven from one side of a loom in succession. This is also the case in the two following modifications.

Alterations in the method of moving a picking arm D have formed the subject of several patents. Two only of these will be described. The first was patented by

A. Lees and J. Clegg in 1857. Instead of lifting the shaft E axially, these inventors hinge the arm D to E, as in Figs. 192, 193, and provide a cap-bearing G which only permits of rotary movement in E. The latch D rests upon a lever P, and a cam L acts through P to operate D. In order to miss a pick, the full side of L lifts D above the striker C. At other times D faces C.

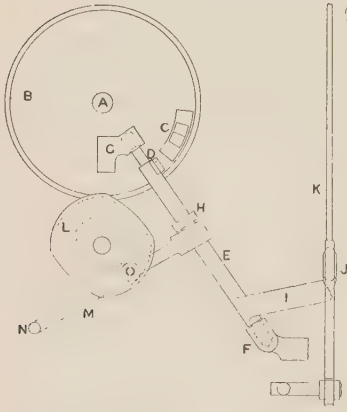


FIG. 190.

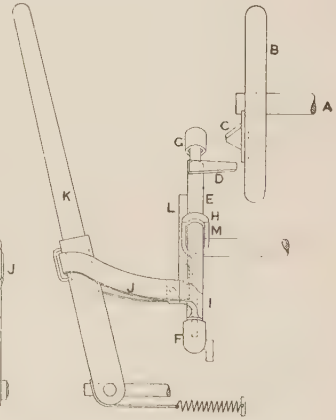


FIG. 191.

In 1883 W. Yates invented an upper bearing G, Figs. 194, 195, having an inclined plane, formed by placing two flanges obliquely to the framing. The top of the shaft E is free to move in the groove of G, and the shaft rests against the face of a cam L. This cam is set-screwed upon a light shaft and is driven by wheel gearing from the crank shaft: as L revolves, E is pushed up, and out, until the arm D is beyond the reach of the striker C.

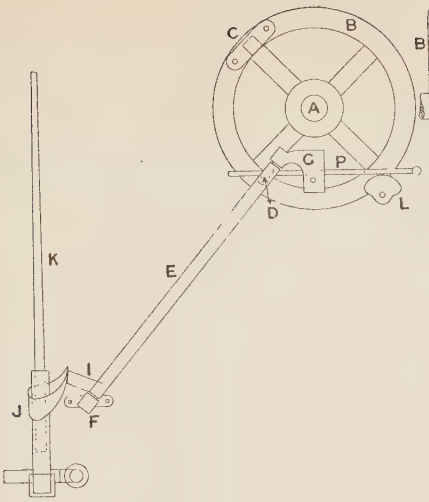


Fig. 192.

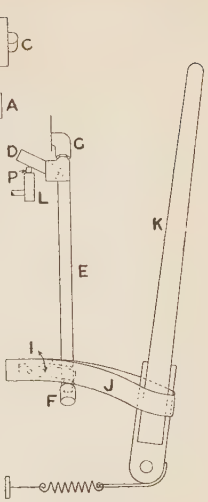


Fig. 193.

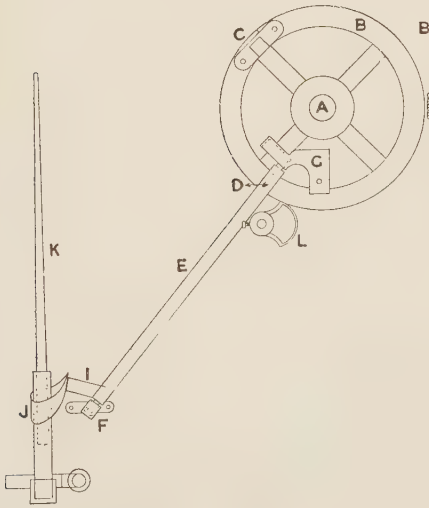


Fig. 194.

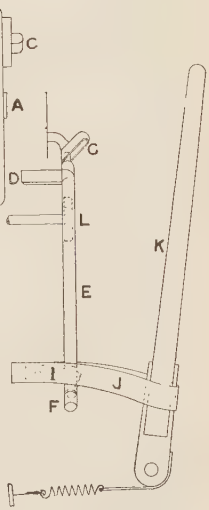


Fig. 195.

Scroll Picks

A scroll motion was introduced by Luke Smith in 1843, the object being to lift a striker C, Figs. 196, 197, 198 out

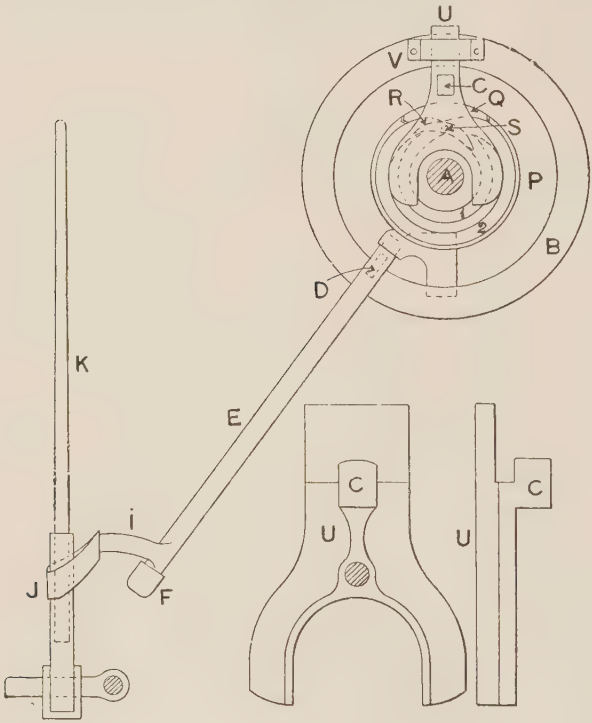


Fig. 196.

of range of an arm D by a stationary scroll P. A scroll is bolted to the end framing and bored to admit the crank shaft A; it consists of beads cast on one side of a disc in such a manner that two grooves 1, 2 are formed to run into

each other at the point P′, Fig. 198. Over P′ a movable

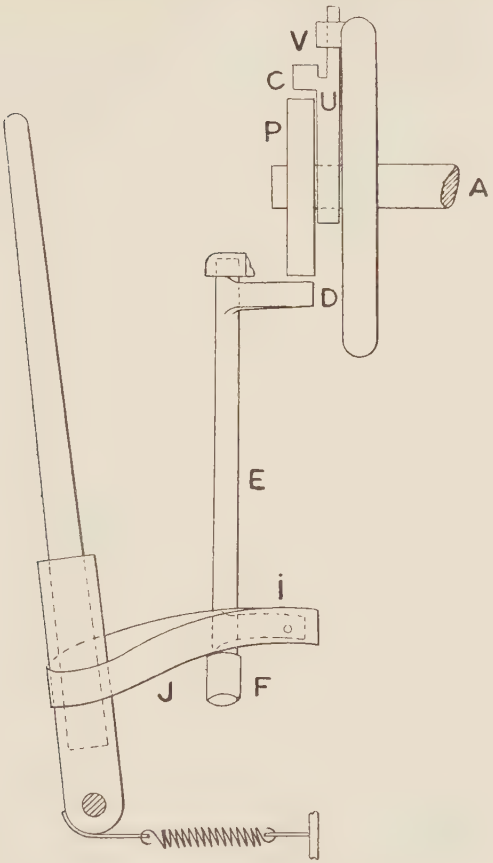


FIG. 197.

piece Q is curved inward for the purpose of turning a half-moon R out of one groove and into the other.

As the fly-wheel B rotates, Figs. 196, 197, a half-moon R

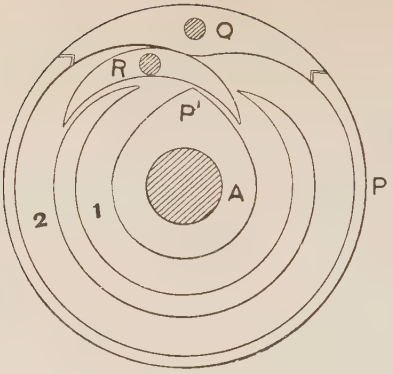


FIG. 198.

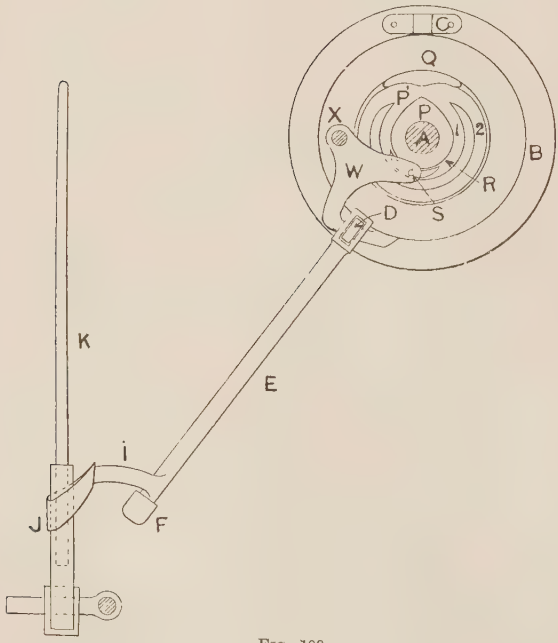


FIG. 199.

travels in the grooves 1, 2. The half-moon is connected to B by a stud S, which passes through a hole in the striker bracket U. A clip V is bolted to the fly-wheel B to carry U round with the wheel, also to permit it to slide in and out upon the face of B. The striker C is thus moved in when the half-moon R is in groove 1, and out when it is in groove 2. In the latter position the striker C is brought into contact with the arm D, and a pick is delivered.

In 1889 A. Clegg obtained a patent for a modification of the foregoing. It has a revolving scroll, Fig. 199, which lifts a latch D above a fixed striker C on the fly-wheel B when a pick is to be inoperative, but C, D make contact when a shuttle is to be moved. A three-armed lever W is hinged to the framing at X ; a second arm passes beneath a latch D, and the remaining arm supports the half-moon R upon a stud S. The latch D is lifted whenever R is in groove 1, and lowered to pick whenever R is in groove 2.

If these contrivances are superior to those illustrated by Figs. 190 to 195, their advantages are not very apparent. The half-moons are frequently broken, the wear and tear is considerable, and scrolls do not lend themselves to conversion into pick-at-will motions.

Cone Under-Pick

The picking motion made by H. Schroer has been designed for and applied to silk looms, but there does not seem to be any reason why it should not be applied with advantage to cotton looms where an under-pick is desired. It is extremely smooth in its action as compared with any other under-pick, and this appears to be due mainly to the application of the cone picking principle to an under-pick motion.

Positive Picking

Positive picking dates back to the year 1678, when M. de Gennes attempted to weave by automatic machinery. It has been a favourite problem with mechanicians of many succeeding generations, but little real advancement has been made. The most extensively used motion of this class, for other than small-ware looms, was introduced by Lyall in 1868, and modified by him in 1870 and 1872; it contained many good features, and was less complicated

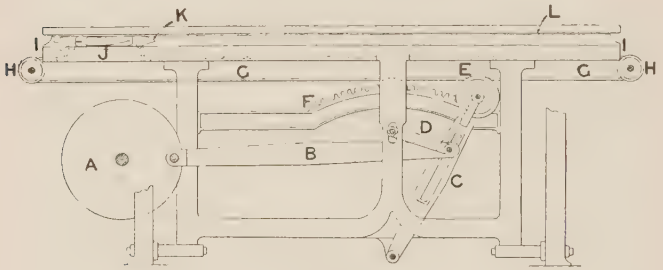


Fig. 200.

than some of the negative picks in general use, but it met with little favour in this country.

Lyall's mechanism is illustrated in Figs. 200, 201. A disc crank A is driven from the loom shaft by an end shaft and bevel wheels. Motion is conveyed from A by means of a connecting rod B to a block placed in a slotted arm C. A link D is also pivoted to the slay and attached to the block; as A revolves the block is moved up and down the slot, and C moves to and fro. At its upper extremity C carries a pinion and also a band wheel E; the former engages the teeth of a fixed curved rack F, which sets up a rotary movement in E as C oscillates.

A band G is wound round the periphery of E, led over two sheaves H, situated at opposite ends of the slay I, and the ends of G are connected to a carriage J. The carriage is mounted upon four wheels and placed upon a metal bed in the slay bottom. Hence as C vibrates the carriage is moved across the warp space to the right and left alternately.

The wheels are in pairs on horizontal pins fixed near the ends of the carriage J, Fig. 201, numbered 1, 2. The wheels 3, 4 project above but are journalled in J, so that they turn by contact with 1, 2. A shuttle K is placed upon and drawn to and fro by the carriage J. Two shuttle

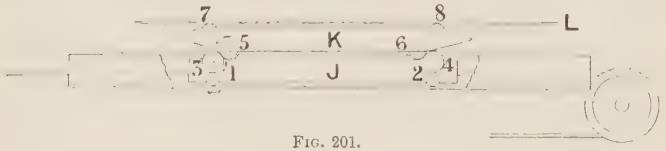


FIG. 201.

wheels 5, 6 rest against the insides of the wheels 3, 4, and two other wheels 7, 8 roll along the under surface of a bevelled rail L. By this arrangement a shuttle is held securely in its place.

Assuming a right to left motion to be given to the carriage and shuttle, the wheels revolve in the direction indicated by the arrows, and with the same surface velocity. Wheels 3, 4 lift the warp threads successively for the wheels 5, 6 to roll over without imparting a lateral movement to them. A shuttle moves at a constantly accelerating pace from one side to the centre of a fabric, and from the centre its velocity is correspondingly diminished until a pause is reached on the opposite side. This arises from two causes: the first is due to the crank A and the connect-

ing rod B, and the second to the action of the link D. A shuttle begins to move when A is passing from its front or back centre. While A is on those centres the arm C is for an instant in a state of rest; but immediately either of them is passed the arm begins to move slowly, and increases in speed until at the bottom or top centre of A the forward velocity of C almost equals that of the crank pin, then a corresponding decrease takes place to the next centre. In the second place, as the arm C moves from either extremity of the rack F, the block is pushed by the link D nearer the fulcrum of C, to develop a greater velocity in the shuttle. The carriage and shuttle wheels are necessarily small in diameter, they cannot be lubricated, and yet, at a shuttle velocity of 44 feet per second, they would have to revolve several thousand times per minute. This is one of the weakest features of the invention.

The Zapata Picking Motion

An interesting development of positive picking is the one invented by the late Dr. Zapata, at one time Columbian Minister to Great Britain.

The weft mounted on a spindle or peg is contained in a cylindrical metal case with a pierced pointed end through which the weft passes. The metal case rests on a carriage and is drawn through the shed in a manner somewhat similar to that of Lyall's picking motion.

The metal weft case lies parallel to the warp and therefore the weft is laid well forward towards the fell of the cloth.

Another novel feature of the loom is that there is no moving slay, the weft being pushed into place by means of a revolving comb, so that the beating up is of a sectional

character and follows the weft as it emerges from the weft case.

Owing to the death of the inventor the loom, which contains many interesting points, remains undeveloped, and the original is installed in the College of Technology, Manchester.

PART XI

PICKERS, PICKING BANDS, CHECK STRAPS, AND BUFFERS

As a shuttle enters a box a picker is very severely taxed, for the former delivers a blow, from a steel point, which cannot be distributed over an even surface. It has been estimated that on entering a shuttle box a calico shuttle strikes a picker with a force equal to a 1 lb. weight falling 3 feet; and as these looms make upwards of 200 picks per minute, it is not surprising that the wear and tear of pickers forms a serious item of expense in a weaving mill.

Pickers are made in a variety of forms and materials according to the requirements of a manufacturer. The materials used are buffalo-hide, leather, wood, iron, brass, canvas, and rubber, but the first named is in most general use. To be of real service pickers should be of good quality, well seasoned, of equal weight, and made from as few pieces as possible. A variation of $\frac{1}{5}$ of an ounce should not be exceeded for a given loom.

Picker-making is a separate industry, and numerous operations have to be performed before a finished article is obtained. They are briefly as follows:—The hides,

shipped from India, Buenos Ayres, and other places, in a hard and hairy condition, are on arrival in this country steeped in clean water for one week, then in lime pits for from four to six weeks; the hair is next scraped off, and the skins are hung up to dry for from four to six weeks. In this condition hides are often sent to the picker maker, who macerates them in water until they are soft enough to retain any shape given to them. Hides are next cut into strips to correspond with the size of picker to be made—ordinarily about $3\frac{1}{2}''$ by $1'\ 0''$. This is followed by rounding, notching, and punching, after which the strips are passed through rollers and shaved down to a uniform thickness. Matching is the next operation, namely, strips of equal weight are selected, or failing that, equality is obtained by adding smaller pieces which at a later stage are folded inside the larger ones. After matching, the pieces are drilled, a staple is inserted, they are riveted, roughly shaped, and pressed by powerful machinery into a usable form. Finally pickers are slotted, punched, drilled, and sent to the manufacturer, but are by no means ready for use, as when new the moisture they contain renders them more or less pulpy. Pickers should be threaded upon a string and dried for six or more weeks in a place where there is a constant current of moderately warm air. They are next saturated in Gallipoli oil to increase their durability. But if pickers are not thoroughly dry before immersion, the oil will prevent the moisture from evaporating. If they are merely immersed in oil, three or more months will be necessary to effect complete saturation, but by the aid of a force-pump a few days will suffice. Then follows a gradual drying for from six to eight weeks.

Leather pickers are chiefly used on under-picked looms; they are often constructed by folding up several strips of

leather, each being equal to the depth of a picker, and securing the strips with rivets. Sometimes a picker is made by folding one piece of leather which is three times the depth required ; this plan gives strength, firmness, and smoothness. At other times pickers are prevented from bursting at the sides by placing a thin strip of steel between the outer and inner layers of leather.

Picking Bands

Good strapping is of equal importance with good pickers ; the best quality of leather, although more costly at first, is cheapest in the end, for it neither stretches so much nor breaks so soon as inferior qualities, and looms fitted with it are stopped less frequently for repairs.

A few picking arms are still slotted as at C, Fig. 176, but the majority have a ring groove made near the forward end for a picking band to enter. The end may be fashioned into a truncated cone and shielded with metal, so that the coned surface shall correspond, as nearly as possible, with the angle formed by a picking band and the arm when a pick is delivered. Or the end of the arm may have a lip into which a band is dropped edgewise. The methods of attachment also vary, and differences of opinion exist as to the best length of band, and the most economical way of connecting it to a picking arm and picker. While some prefer bands of from 12″ to 14″ long by $1\frac{1}{8}$″ to $1\frac{1}{4}$″ wide, others contend that bands from 23″ to 50″ long possess advantages over shorter ones. Both single and double, straight and tapered, bands are used, some being directly connected to the arm and picker, others to one or even to two secondary straps. For most looms, green, oak-tanned, or chrome bands are employed.

The following are a few of the methods of applying bands to narrow cone pick looms :—One end of a tab 8″ to 9″ long by 1″ to $1\frac{1}{4}$″ wide is pushed through the side and top slots of a picker; both ends are brought together, and a slit of about 2″ is made in them for a picking band to pass through; the latter is 23″ to 24″ long. Holes are punched at both ends of a band from $\frac{1}{2}$″ to $\frac{5}{8}$″ apart to facilitate length adjustment; the band is next bent round the ring groove in the arm and sewn across, both ends are inserted into the slotted tab, and secured by forcing a wooden peg, or a leather plug, through one pair of holes.

A band, from 23″ to 27″ long, may have a longitudinal incision made near its centre, and after fitting it in the ring groove in an arm, one end is drawn through the slit until both ends are level, then, as in the previous arrangement, the ends are passed through a slotted tab on the picker and fastened with a peg. A piece of string tied round the band, immediately below the arm, holds the band in position. This plan is often preferred to the first named.

A short, single band may have a slotted tab, 9″ long by $1\frac{3}{8}$″ wide, sewn upon an arm, and riveted with a wire staple to keep it in the groove. A band, 12″ to 13″ long, is then slit near one end and punched near the other; it is passed through the front and top grooves in the picker, the punched end is threaded through the slit, drawn tight, and made fast by a peg to the tab on the arm.

Single bands, 25″ to 50″ long, have one hole punched near the lower end, and an indefinite number of holes punched, about $\frac{3}{4}$″ apart, near the other end. The band is drawn through the front and top slots of a picker, and a piece of leather is pushed into the single hole to prevent

the band from slipping out when working. The free end is twisted spirally round the arm, and a wire pin, driven into the arm, passes through one of the holes to retain the band in position. A wire staple, or a strip of leather screwed to the arm, bridges the ring groove and holds the band in its place. Instead of employing a leather plug to connect a band and picker, a band may be slit near a picker, and the punched end passed through the slit to couple them. Long bands are advocated for the reason that they generally break near a picker, and the damaged part of a long one can be cut away, a portion unwound from the arm, a fresh hole may be punched, and the band again secured at both ends as before. A similar operation may be repeated several times; but a short band when once broken admits of few readjustments.

A band may be double, if each end be passed through a separate side slot in the picker, and both drawn through the top slot, and also through the loop thus formed. A band may be bolted to a picker, or it may be held by metal clips secured upon a picker. But whatever the method adopted, a band should not touch the box spindle or it will wear rapidly.

The Check Strap

Robert Pickles claimed to have invented the check strap in 1839, but it was patented by Crook, Eccles, and Lancaster in 1845, and is now fitted upon quick-running looms, whether furnished with a fast or a loose reed. A check strap is a simple and effective contrivance for destroying the momentum of a shuttle as it enters a box.

It consists of a leather strap A, Fig. 202, about 1″ wide and of equal length with a slay. It is supported by four

guides B, which are screwed to the slay front, and permitted to partake of a sliding motion. At its centre a piece of leather C, $\frac{1}{2}''$ long by 1″ deep, is nailed to work between two centre guides, that allow $3\frac{1}{2}''$ of traverse in A. Each end of A is secured to a tab D, 6″ long and $1\frac{1}{2}''$ wide; both tabs are punched near one end for a picking spindle to pass freely through, and both are slit at the other end to receive the strap A. When in position A is fastened to D, D by a piece of wire. Instead of slotting the tabs, a buckle may be sewn upon each, for either plan provides a ready means

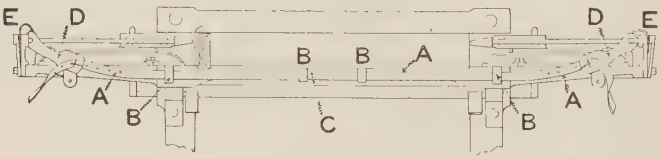


Fig. 202.

of adjustment. The tabs D are placed upon the spindles but behind the pickers. A strap A is not adjusted until the loom is ready for work; it is then usual to place the cranks upon their bottom centres, and, when one picker is at the box end, to tighten A until the remaining picker is slightly more than 1″ from the end of the other box. Two pieces of leather E, called guards, are about $1\frac{1}{2}''$ broad by 5″ long, and punched at both ends. One end of each is pushed on a spindle in front of a tab, the other goes behind a spindle plate. If E, E are properly adjusted a check strap will work satisfactorily, even if the piece C be removed. If spiral springs are employed to check the momentum of a shuttle, a collar is loosely mounted on a box spindle behind a picker and so shaped that it impinges against a spiral spring threaded upon a supplementary spindle. A

spring is compressed each time a shuttle enters a box. Should a picker strike a box end, the shuttle will rebound, a cop will be knocked off, or the shuttle pin will be broken. These defects may be due to a check strap being imperfectly adjusted, to a pick being too strong, or the swells too weak. Spindles are fixed over shuttle boxes in various ways; some have caps set-screwed over them as in Fig. 202; others are screwed at the outer end, and locked by nuts. A spindle may also pass through a forked clip furnished with a screw and lock nuts, and through the box end; the clip then impinges against the box and holds the spindle secure.

Buffers

A buffer should prevent a picker from striking a spindle stud; it may consist in superposing three or four pieces of leather, all 6″ long by 1″ wide; then folding them to bring the ends together, and riveting them with a wire staple, but a loop is left large enough for a box spindle to pass through, and a slit made near the free end. Into this slit one end of a strap is pushed and fastened by a piece of wire, the opposite end is bolted to the slay front. A buffer may be made by doubling a strap at one extremity, and punching it to receive a spindle, the opposite end being treated as described above. By another method a leather band is closely coiled and a hole is cut through the coils for a spindle to enter; the straight end is then secured to the slay. Or, instead of connecting the straight end of a buffer strap to the slay, that strap may be looped and connected to the free end of a bow-spring which is bolted upon the slay.

PART XII

WARP-PROTECTORS, OR FAST AND LOOSE REED MOTIONS

If, from any cause, a shuttle fails to reach its proper box, a loom must either be instantly stopped by a fast, or gradually stopped by a loose, reed motion. In the latter event a shuttle may remain amongst the warp while the slay vibrates, without doing damage. All looms are provided with curved levers or springs, called swells; these, in fast reed motions, serve the twofold purpose of preventing a shuttle from rebounding after entering a box, and of protecting the warp from injury should a shuttle remain amongst the warp as the slay advances to beat up.

The fast reed stop motion was patented in 1796 by Robert Millar, but has been greatly improved by later inventors. It now consists of two swells A, Figs. 203, 204, which are often made of iron, although many wooden ones are to be met with. One of the chief defects of a wooden swell is that it wears rapidly at the shoulder. It has then either to be replaced with a new one, or planed to its original shape. A simple method of preventing wear, and also of increasing or diminishing at will the obliquity of its surface, was patented in 1893 by Messrs. Collier, Evans, and Riley.

The invention is shown in Fig. 204, where a swell front A has a thin steel coating B firmly secured upon it at C, and at D a screw is passed through a slot in B to hold the rear end. At E a screw F passes through the wood and is retained in position by a lock-nut and a plate G, affixed to

the back. Upon F a second nut H is made to impinge against the inside of B, hence by screwing or unscrewing F

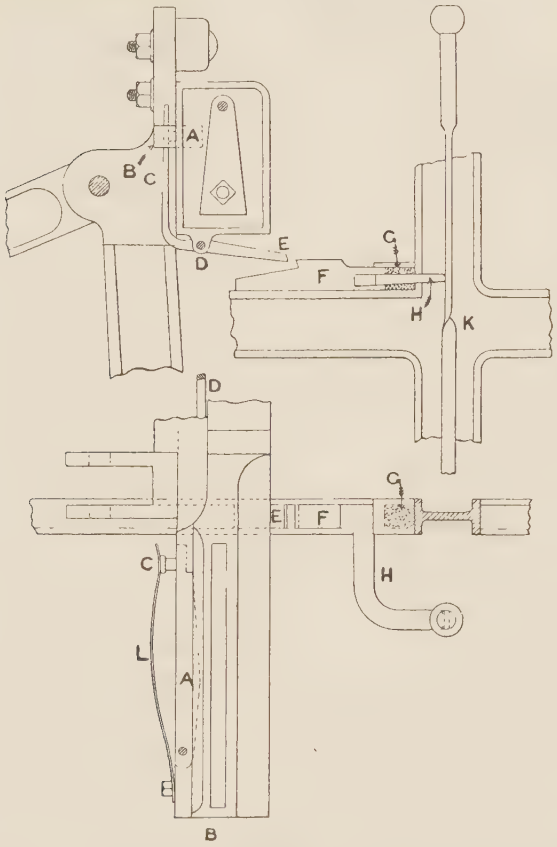


FIG. 203.

the shape of a shoulder can be altered. B also provides a partially elastic cushion for a shuttle to strike against. A swell A, Fig. 203, is usually hinged to the back and near

the outer end of a shuttle box B; its curved face is made to protrude inside B, by a lever C and a blade spring L. A blade spring has been coiled at one end like a watch spring, and the coiled end fastened to an adjustable pin. But, however shaped, a spring puts a shuttle under control, and reduces wear and tear. In 1894 T. Pickles and B. Blakey patented a swell that permits of movement about its longitudinal and transverse axes. This swell is made from two pieces of wood, the back piece having the grain running length-wise and the front piece cross-wise. The ends are convex and rest against the box back, hence the latter limits the inward movement, while a blade-spring holds the swell forward. A swell so constructed and controlled can move in and out throughout its entire length, and also make a rolling movement. Its control over a shuttle is, therefore, more efficient than that of a hinged swell. A shuttle box is invariably wider than a shuttle by at least $\frac{1}{8}''$ at the outer end, and often by $\frac{1}{4}''$ at the entrance. When a swell is placed in a box back, a shuttle is pressed against the box front, and therefore out of line with the reed. Further, a shuttle will not be moved in a straight line, for when it is fully boxed, a swell tends to tilt its tip away from the reed; but when acting near the outer end of a shuttle, the tip is tilted towards the reed, and the change from one position to the other occurs in a moving shuttle.

A swell may be placed in front of a shuttle, in which event it is generally made of malleable iron, so that, by bending the swell, its shoulder may be increased or reduced in size. A box front may then be dispensed with, and any shuttle in a multiple box loom is free to be adjusted by hand without disturbing the boxes. By exerting pressure upon the front of the shuttle, a swell, if suitably made and

operated, will hold that shuttle against the box back, and therefore in line with the reed. If faulty in construction or action, a front swell may tilt the tip of a shuttle away from the reed at the moment it leaves a box.

Below a swell B a rod D oscillates in bearings shown attached to the slay sole, but such bearings are preferably fixed upon the swords. The rod D extends across a loom, and upon it two levers C are set-screwed to rest against the swells A: upon D, two flattened blades E are also welded. In front of, and directly in the path of E, two buffers F, known as frogs, are each provided with a shoulder to engage the blades E whenever a shuttle is absent from a box

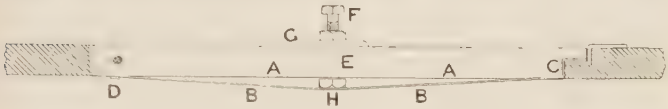


FIG. 204.

as a slay advances to beat up. Both frogs F rest upon a portion of the framing with their forward ends abutting upon rubber cushions G, or spiral, or flat springs. One frog F may be connected by an arm to a break on the fly-wheel, so that a forward movement in F will put a drag upon the wheel, and speedily bring a loom to a state of rest.

In order to avoid slipping, the blades E and the frogs F dovetail into each other. When in contact they could, without other aid, bring a loom to a sudden stand, but violent shocks of impact between E and F would thereby occur while the driving strap exerted its full force to carry the slay forward, and breakages would result. This defect is avoided by attaching an arm H to one of the frogs F, and placing its free end immediately behind the starting handle

K ; then as that frog recedes from the blow of E, the arm H will partake of a similar movement, push the handle K out of its notch, and transfer the driving belt to the loose pulley. The blade springs L may press upon the arms C and so assist in holding the blades E in striking position, or a spiral spring may be hooked upon the under side of E and upon the bracket on a slay sword to effect a similar purpose. So long as a shuttle is moving correctly a loom will continue in motion ; for, as the former enters a box, it pushes back a swell A and an arm C far enough to lift E clear of F ; but should a shuttle fail to reach a box, the parts remain in their normal positions and the loom is stopped.

The points requiring most attention are : the length and position of the blades, and the size and shape of the swells. Some loom builders employ a single blade E, but two blades are preferable, as a slay is then less liable to twist. The blades should be long enough to avoid breaking the threads when a shuttle is in the warp as a slay advances to beat up. But if the blades are too long they will strike the frogs before a shuttle has time to lift them clear. They should be from $\frac{1}{8}''$ to $\frac{1}{4}''$ above the frogs when a shuttle is fully boxed. A rod D should be mounted upon the swords, and hold the blades E horizontal when in contact with the frogs, for then the rod centre sustains the shock, and there is no risk of it rotating. If a rod centre is above the frogs, its tendency to rotate will be proportionate to its elevation, and part of the energy of impact will be transferred to the arms C. If the springs upon the blades are too strong, increased force will be required to drive a shuttle, and, in addition to waste of motive power, both shuttles and swells will wear rapidly. Worn swells, narrow shuttles, and wide boxes cause a loom to stop when it should be active, and

worn blades, worn frogs, and weak springs allow a loom to run when it should be stationary. A fast reed motion throws considerable strain upon many parts of a loom, but the rigidity of the reed recommends it for the production of heavily wefted fabrics.

Loose Reed Motions

In 1834 Hornby and Kenworthy patented a loose reed motion, which was improved by Bullough in 1842, and by many later inventors. For light, fast-running looms it has remedied most of the defects of the fast reed motion; by its aid a starting handle is moved from its driving detent immediately a shuttle is trapped, but the loom cranks may make several subsequent revolutions without injuring the warp.

The parts of a loose reed motion are shown in Fig. 205, where the reed A has its upper rib pushed into a groove in the slay cap B, so that B may form a pivot for A to swing upon. C is a strip of wood, or a bar of iron, extending across the loom; it is supported by and pressed against the bottom rib of A by the action of a series of arms D, which are fixed upon a rod E, that resembles the stop rod of a fast reed loom. An additional arm, furnished with an adjusting screw, is also secured to the rod E. By pressing against the rear of a slay sword this screw regulates the pressure of C upon the reed A. A rod E has two curved levers F set-screwed upon it at equal distances from the swords. As a slay moves forward the ends of F are carried against the upper or lower faces of two wedge-shaped frogs G; these latter are held rigidly in brackets H, bolted to the framing. When in its driving position, a starting handle J holds a buffer K facing a dagger I upon

the shaft E, but normally the point of I is below the corrugated surface of K. Outside the end framing an arm upon E carries at its extremity an antifriction roller L; as the slay falls back, L makes contact with a bow

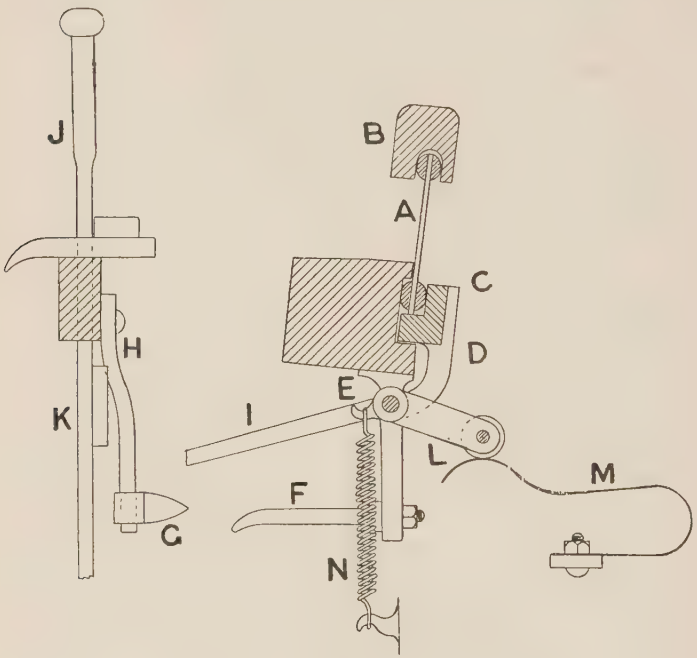


FIG. 205.

spring M, bolted to the framing. The function of the parts L, M is to steady the reed A as a shuttle moves across the warp. Two light spiral springs N are attached to hooks on the rod E and the slay swords respectively; they hold the reed steady when I, M are apart, but they permit A to yield to any unusual pressure.

Should a shuttle be trapped in the warp a reed must give way freely, but it must be rigid when weft is to be beaten up. To accomplish the latter the fingers F will, when the reed and fabric are in contact, have passed beneath the points of G $\frac{3}{8}''$ or $\frac{1}{2}''$, and the bar C should bear tightly upon the reed A, to ensure a smart blow upon the weft. When the driving cranks are on their top centres, only the force stored in the springs N is available to prevent the reed from falling back. At this time the space between F, G will vary with the throw of the cranks, but in calico looms it is about $2''$, so that in case a shuttle is trapped, the warp resistance will be sufficient to stretch the springs N, force back the reed A, and cause the bar C to lift the levers F upon the upper slopes of the frogs G; the dagger I should then strike the buffer K. If K and I are not properly adjusted to each other, the reed-case C will liberate the reed A before contact is made between K and I. In that event, I will sink below K without pushing the handle J out of its driving notch, and the loom will continue in motion until the weft fork causes it to stop. In some looms a pendent catch holds I up and thus ensures its correct action.

While the dagger I pushes the starting handle from its detent, the levers F and the frogs G release the reed A, and the loom is stopped without violent concussion. Owing to the difficulties experienced in making a reed sufficiently firm to beat up, and sufficiently sensitive to prevent a trapped shuttle from damaging a warp, loose reed mechanism is ill adapted for the production of heavy fabrics. Attempts have, however, been made to combine in one device the advantages of a fast with those of a loose reed.

In 1879 T. Sager patented what he designated a "fast

and loose reed motion." By this invention he aimed at locking the reed just before and while the weft was beaten up, and unlocking it at any desired point without the application of external pressure. It consisted in attaching a bracket to the end framing for the support of the lower end of a link, whose upper end was secured to a catch fulcrumed upon a slay sword. In place of the levers F, a pendent arm was keyed upon a stop rod E. As a slay advanced to the cloth fell the link lifted the catch into the path of the pendent, and both became locked when the reed was $\frac{1}{2}''$ away from the cloth fell. As a slay receded from the fell the link drew down the catch and loosened the reed. By an alternative plan, the catch was provided with a curved slot to receive a bowl, fixed upon a pin in the framing. As a slay moved the curved slot against the bowl, the catch rose and fell.

In 1889 Messrs. J. W. Shorrock and J. K. Hacking patented the application of a hooked bracket, which passed through a slot in the back board of a shuttle box, and was loosely mounted on a picker spindle. As a shuttle entered a box, it pushed back the bracket until the hook passed over a lever from the stop rod, and locked the reed. So soon as a shuttle left a box a spiral spring moved the sliding bracket forward and released the reed. In case a shuttle did not reach a box the stop rod lever was not acted upon and the reed was free to be pushed back. See also p. 435.

Swells in a loose reed motion prevent a shuttle from rebounding, and assist in guiding it while under the influence of a picker. If they are defective, the cops are liable to be knocked off, and the shuttles, pickers, and bands wear rapidly. Many loose reed swells are similar to those used with fast reeds, but a fulcrum pin has a

tendency to convert a swell into a wedge, and remove a portion of the swell from a fully boxed shuttle.

In 1890 Messrs. W. Harker and J. Grayson patented a double spring which controls the shuttle better than most swells, for it changes its position with relation to the shuttle, and when the latter is driven home, the entire length of the spring is effective.

Fig. 206 is a plan view of this swell: A, A is the back board of a box, B is a bolt and C a screw, which fix the spring D in position; at E the spring protrudes slightly

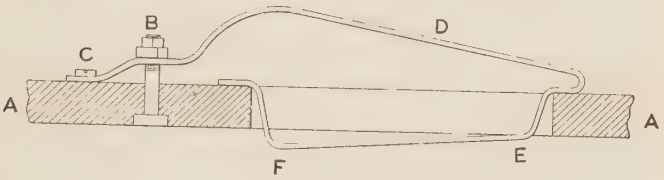


FIG. 206.

in front of A, but at F it is $\frac{5}{16}''$ beyond A. When a shuttle is received it engages the spring at E, and D gives way; but when it is more than half-way in a box, the spring gives way at F and acts in conjunction with D.

PART XIII

SHUTTLE-GUARDS

WITH every increase in the speed of a loom flying shuttles became a source of greater danger to work-people, and eventually guards were rendered imperative. From the

year 1868, when Wrigley and Wright obtained the first patent, to the present time, inventions for shuttle-guards have been both numerous and varied. But a simple and reliable appliance for preventing shuttles from flying out without entailing additional labour upon the weaver is still a desideratum. In practice most of the available guards are found to be inefficient at some point. They may be weak in construction, imperfectly fitted, cumbrous, or complicated, or by casting shadows upon the warp and fabric may prevent a weaver from detecting faults. After being in use for a short time, the brackets often break or become loose and require frequent attention. A guard should be secured to a slay cap by bolts, and the moving parts should have broad, firm bearings.

Few guards will, under all circumstances, prevent a shuttle from flying out, but most of them prevent it from flying up ; and as the latter evil is more to be feared than the former, even imperfect guards serve a useful purpose. If more of them were constructed to withstand the severe shocks occasioned by beating up, it is probable they would be welcomed by weavers instead of being merely tolerated.

Wing and Rigid Guards

Guards are of four classes—namely, wing, rigid, semi-automatic, and automatic. A wing guard does not prevent a shuttle from being ejected, but it generally prevents injury to work-people. It consists of a piece of wood, or of framed wire netting, which is rigidly held between two slay ends, and its function is to catch a flying shuttle. In breadth it corresponds to the distance between the breast

beam and the most backward position of a slay. For general work, guards of the second class have met with most favour. They may consist in bolting two or more metal brackets, each 4″ to 5″ long by 2″ broad, upon a slay cap. These brackets hold a fixed rod about $\frac{1}{2}$″ in diameter over the shuttle's course, slightly above the upper warp line, and from 2″ to $2\frac{1}{4}$″ in front of the reed. Other guards are made by bending an otherwise straight or a wavy rod at each extremity, to enable it to be bolted upon a slay cap and project in front of the reed. In 1896 J. Holt patented a guard which is typical of many stationary ones: it is made by screwing a number of light, malleable iron brackets, about $\frac{5}{8}$″ wide, upon a slay cap at from one-half to three-quarters the length of a shuttle apart. Each has its foot bent to be parallel with, and only slightly elevated above, the upper line of warp. Such a guard offers little obstruction to light or to manipulation of the warp. All fixed guards are simple, yet they cannot prevent a shuttle from flying out at the edges of a fabric, for at these places there is no guide of any kind. But an iron plate may be bolted on a slay front near the entrance to each shuttle box, and bent over to the cap. Such plates are spoon-shaped, to catch a flying shuttle, yet what a weaver gains by them in safety is lost in increased labour when changing shuttles.

Semi-automatic Guards

Semi-automatic guards are varied in structural detail; but they should automatically move into working position at the first beat of a slay. R. Hall and Sons bolt two brackets upon a slay cap to serve as bearings for a swivelling guard bar, made of $\frac{7}{16}$″ round iron. When this bar

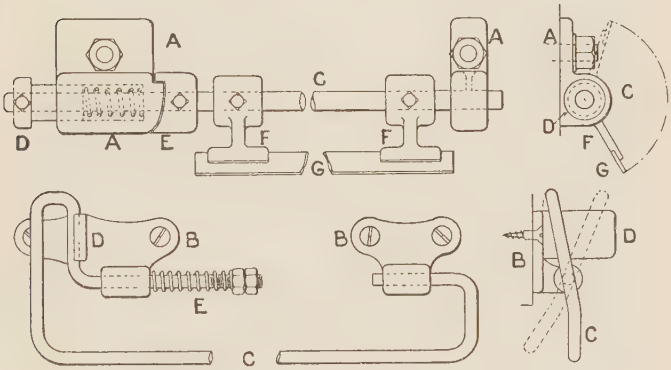
is in working position it is locked by forcing it over two conical pins situated in chambered recesses in the brackets, and against fixed stops. A spiral spring is placed in each recess, and the shank of a conical pin passes through the spring, also through a hole at the back of the chamber, where it is secured by a nut. Each pin will therefore slide back when sufficient pressure is brought to bear upon it. Before drawing warp into the reed, a guard bar is turned up manually to rest upon the slay cap. When so placed it does not interfere with the weaver's movements, but before restarting a loom the guard must be turned down again manually. The manipulation consists in moving the bar up and down; beyond this the contrivance is simple and firm.

Guards have been constructed from two flat bars that extend across the warp, and open and shut like a parallel ruler. When open the bars are rigidly locked, and one of them passes in close proximity to the temples. This introduces an element of risk to the weaver, as the blade and the temples act as shears.

In 1892 G. E. Hamblet and H. Clifton bolted two brackets A, Fig. 207, upon a slay cap to form bearings for a light shaft C. One bracket has a clutch face, and is chambered out to admit an open-wound helical spring. The shaft C passes through A, A, and upon one end a sleeved hoop D is fixed with a set-screw. The sleeve of D enters the chamber, and the spring impinges upon it, and also upon the bracket. A collar E with a clutch face is also fast upon C, both halves of the clutch are united by the spring to normally hold the guard over the shuttle race. The shaft C carries a set of arms F, for the support of a flat bar G. In case warp threads are to be drawn in, G is turned up by hand, and the inclined surfaces of

A and E compress the spring. When a loom is started the vibration produced by beating up is sufficient to cause C to slide longitudinally and place the guard in its active position.

In 1894 C. Marshall patented one of the most successful of these inventions. It is mounted upon a slay cap in brass brackets B, Fig. 208, and consists of a cylindrical rod C, which is bent at both ends, and cranked in the



FIGS. 207 and 208.

middle, where a third bearing is placed. The rod C has an open spiral spring E threaded upon it, and E draws C against a cam face D formed on one end bracket B. The pull of this spring is regulated by a screw and lock nuts; it should be such that vibration in the loom will not give an end-long motion to the guard, but after C is turned up will cause it to move automatically into working position with the first beat of a slay.

Many guards are so constructed that a spiral, or a flat spring will hold a guard against a slay cap when the former

is inoperative, and also hold it steady when operative. Of these T. Yates patented, in 1892 and 1894, one of the best known; its rod is either bent to act as a stop, or a bracket is mounted on the rod to limit the outward throw of a guard. When a guard is half-way out the pull of the spring is in the plane of the guard rod, but when a rod is above or below that position the spring pulls it out of, and into, working position. The adjustment is such that a rod automatically assumes its active position when a loom starts.

Two or more rods of varying thickness have been loosely mounted in stepped brackets, so they could be pushed back by hand to the slay cap. When a loom was started the thinnest rod rolled to the front, the next in thickness was arrested by a decrease in the width of the slot, and if a third rod was used it was similarly stopped before the second was reached.

In 1894 C. H. Wilkinson patented a guard consisting of a plate fastened to a slay cap; on the plate two hinged brackets are so secured that they may be turned against a cap. The brackets are provided with curved slots of varying lengths to hold three rods, and permit one to slide farther from a slay cap than another. At regular intervals chains are made fast to the plate and to the rods. Alternating with the above-mentioned chains are a second series which depend from the plate and the front rod to form loops. Finally, a fourth and shorter rod is slung by chains between the slotted brackets. Should a shuttle rise from the race board, it will be caught in the pendent chains. The rods if pushed back will cause the hinged brackets to turn against the cap, but they will gravitate to their active positions on starting a loom.

Much attention has been bestowed upon the construction

of brackets to hold guards; unless they are considerably in advance of a slay cap, a rod, when pressed back, will fall against the reed face and render it difficult to draw in warp threads. The lubrication of guards is a difficult matter, for the brackets are placed where oil-drops are likely to fall upon a warp. On this account buffalo hide has been tried, as its lasting qualities are great, and it can be used for a long period without oil.

Automatic Guards

The fourth class of shuttle-guards is also a large and varied one. All devices of this kind must contain parts that automatically move out of the way when a loom is stopped, and are automatically restored to their working positions immediately a loom is started. Most of these guards are operated by the starting handle, and therefore they are out of action for two picks before a loom stops; and during this time shuttles are specially liable to be ejected.

When a starting handle is moved to put a loom in action it may vibrate a lever, from which wire connections, and an intermediate lever, convey the movement to a light shaft mounted behind a slay cap. Upon such a shaft two arms are then set-screwed to support two flat bars that pass between the slay swords and the ends of the reed. As the shaft oscillates, its arms and bars thrust one or two rods over the shuttle's course. So soon as a driving handle is moved to stop a loom the rods are drawn back against the upper part of the reed face, in which position they offer little obstruction when warp is being repaired.

An automatic guard-bar has been placed under a cap, and moved in and out by a cam, by levers, and links. It moved out each time a shuttle passed across, and in when a shuttle was boxed. Electro-magnets have also been applied to a shuttle, and armatures to a race, to cause a shuttle to press against both reed and race as it moved across, but without success.

PART XIV

MULTIPLE BOX MOTIONS

Numerous attempts were made to weave by power fabrics that require more than one shuttle, but many years elapsed before success was achieved. In 1792 Dr. Cartwright divided a flat tray into compartments, each large enough to hold a shuttle, and he contrived, by pushing and pulling the tray automatically, to move the proper shuttle in line with a picker. Another inventor placed a series of shuttles inside the segment of a circle, and pivoted the segment above the shuttle race, so that by swinging it to and fro any shuttle could be carried into a working position. A third fixed the shuttle boxes outside the segment of a circle, and fulcrumed it below the race board; but these and other plans were unsuccessful. At the present time shuttles are moved on the "rise and fall" and "revolving" principles. The former was invented and applied to hand-looms by Robert Kay in 1760; but Squire Diggle, in 1845, was the first who successfully applied it to power-looms. Revolving boxes were invented by Luke Smith in 1843. Both principles

are now found in considerable variety of detail, but of the two, rising and falling boxes are most varied.

Multiple boxes may be applied to one end or to both ends of a slay. In the former case alternate picking is imperative, in the latter either alternate or pick-at-will devices are available. A multiple box is longer by from $5\frac{1}{2}''$ to $9''$ than a single box, hence additional floor space must be provided in a weaving shed for such looms.

A box motion should be positive in action, and so connected with other parts of the loom that it will be impossible for the boxes to get out of harmony with the shedding and picking devices whether a loom be moved forward or backward. Provision should be made for stopping either a loom or a box motion, in case a picker or shuttle fouls the boxes, also if the boxes are not moved into their proper positions; failing this, a positive movement will cause smashes. Any shuttle should be capable of being brought into action at any time; and if the movement imparted to the boxes is not a smooth one, vibration will necessitate a reduced speed in a loom. It is undesirable that shuttles should be driven from their boxes when a loom is turned backward, for a weaver must replace them before restarting. Trouble is caused by a loom continuing to run for two or more picks after one weft has broken, for if a breakage occurs immediately before the boxes change positions, two or more picks of another weft will be driven through the warp. These must be removed and the boxes restored to their proper places. If from this data box mechanisms are examined, many will be found wanting in one or another particular.

Negative Drop Boxes—Diggle's Chain

In 1845 Squire Diggle patented an efficient and simple box motion that at once became a favourite, and held its place for many years. For most purposes it has been displaced by more modern appliances; but it is still used on comparatively slow-running looms, where only two shuttles are required. The details have been modified for special work, yet, as generally applied, it remains essentially as Diggle left it.

Motion is derived from a pinion wheel A, Figs. 209 and 210, which is keyed upon the crank shaft, and drives a slide wheel B, containing four times as many teeth as A. Upon the inner side of B a flange or slide C is cast, concentric with its periphery, but C is broken on opposite sides of the centre, and in the middle of each break a stud D is fitted. The slide holds an eight-sided star wheel E stationary, until, on alternate picks, the studs give it motion, by engaging the notches and carrying it through $\frac{1}{8}$ of a revolution. E is supported on a stud in the end framing, and is compounded with an octagonal chain barrel F, round which an endless chain G is passed. G is composed of links of varying thickness; the thinnest brings the top shuttle in line with the picker, and thicker ones are placed to bring the remaining shuttles into picking position at the proper time. In length a link equals one-eighth of the circumference of the barrel F; a chain is formed by passing studs H through holes in pairs of links, and securing them by split pins. The studs are made longer than the links, so that their ends may enter notches in the barrel F. By this means the chain is moved when motion is given to F.

A bowl I revolves on a stud in the lever J, and rests upon the centre of a link in the chain F. The lever

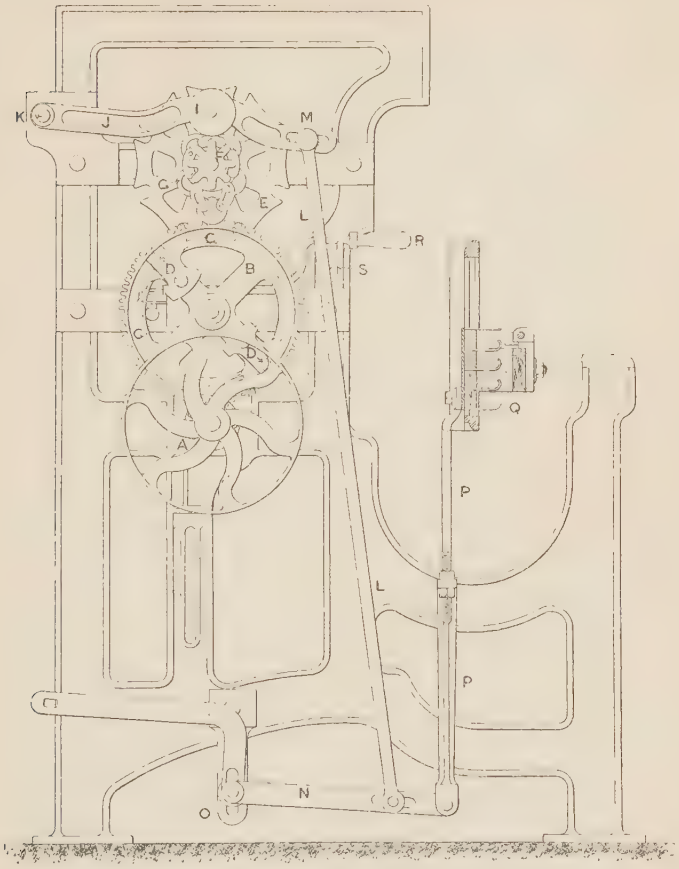


FIG. 209.

J is centred at K; it has a rod L jointed to it at M, whose lower end is attached to a lever N, and N is fulcrumed

at O. Finally a spear rod P connects N with the shuttle boxes Q. When the boxes are lifted halfway, the centre of the pin that connects N, P should coincide with the centre of the rocking shaft. A thick link lifts the bowl I, a thin one allows it to fall, and an up and down motion is thus imparted to the shuttle boxes.

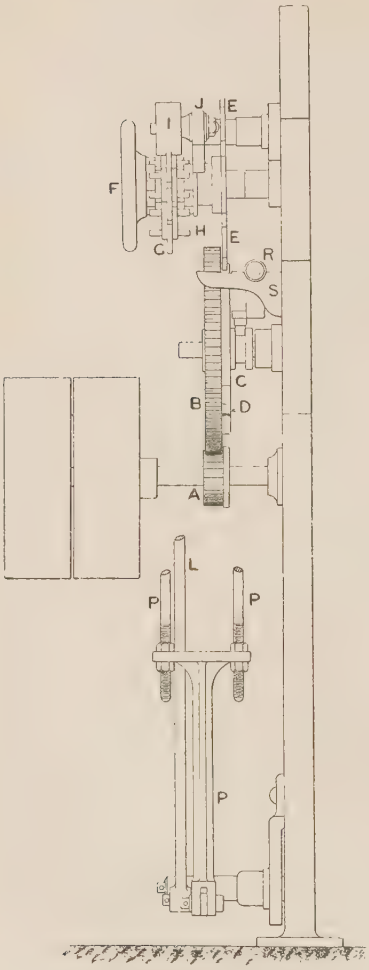


FIG. 210.

If for any purpose it is necessary to move the boxes manually, the slide B must be put out of gear with the star E. This is done by mounting a lever R upon a pin fixed to the framework and causing a stud in R to take into a ring groove in the boss of the wheel B. When R is moved a notched bracket S holds it in position. In 1881 W. Walker connected the slide wheel B to the weft fork for the purpose of disconnecting B, E automatically whenever a weft failed. On restarting a loom, B was automatically restored to its normal position.

Theoretically any shuttle can be instantly moved in line with the race board, but in practice not more than one box is skipped in either direction, for the boxes fall negatively, and if they fall a considerable distance they rebound. This is a fatal defect in high-speed looms. The chain is also ill adapted for long patterns; it is heavy, costly, and if long, it becomes almost unmanageable.

Smith's Link Economiser for Diggle's Chain

In 1858 Mark Smith introduced an important modification of Diggle's chain. By its aid long patterns may be woven with a short box chain, but other defects in the original motion remain unchanged. Smith's additions permit a link to remain stationary until a change in the boxes becomes necessary. A block A, Figs. 211, 212, is fitted loosely on a stud that carries the slide wheel N, and A is rotated by means of two projections that pass from A through N and into grooves in the boss of N. The projections terminate in pins L, for driving a star wheel M. A to-and-fro movement is given to A in order to draw the pins L out of reach of M when no movement in the shuttle boxes is required. The chain barrel O may thus be moved at short or long intervals. The time for movement is determined by a forked lever B, which takes into a ring groove in the boss of A. The lever B is set-screwed upon a light shaft; near its centre B holds a bowl C against a cam D, formed on one side of the slide wheel. The full parts of D thrust C outward and cause the prongs of B to draw out the block A. But the cam D also lifts a lever E, hinged upon a stud, and connected to the shaft of B by a crank and arm F. Upon the forward end of E a feeler G is held over an octagonal card barrel H. The cam D lifts

the feeler G out of the way when the barrel H is partially to rotate. A second star wheel I is secured on the shaft of H to engage with a second slide wheel J that forms part of the boss of N.

The star wheel I moves the card barrel H every pick for

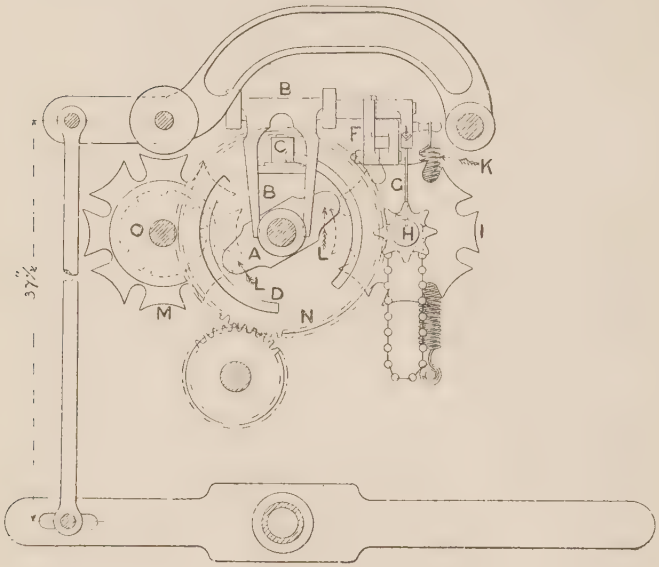


FIG. 211.

pick-at-will looms, but on alternate picks for looms with multiple boxes at one side only. By this means thin steel cards are successively placed under the feeler G. A blank card holds G, F up, and draws the driving pins L away from the star wheel M, but a hole permits G, F to fall; the pins L then engage the star wheel M, and change the boxes. A spring K is attached to a pin in E, and also to

a similar pin in the framing, to hold G in contact with a card on H when the cam D is not acting upon it.

Where dobby or Jacquard shedding is used the barrel H, the star wheel I, and the chain of thin links are discarded, and all shuttle changes are controlled from the shedding motion. This plan not only saves time when a loom is gaited, but it reduces the number of parts that require adjustment after unweaving. In place of the discarded parts a light lever is mounted upon a vertical pin, and

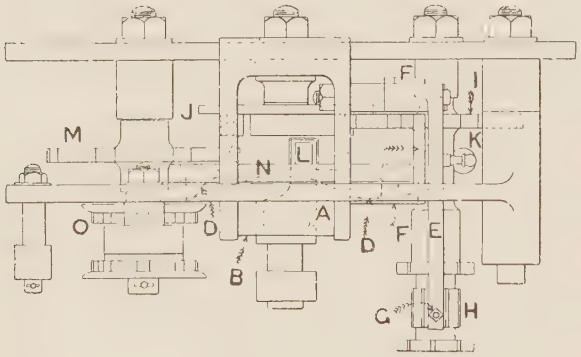


FIG. 212.

one end of this lever passes beneath the feeler G to serve as a blank card. By moving the lever the feeler is free to fall, and that equals a hole in a card. A cord attached to the shedding motion withdraws the lever from G and a spiral spring restores the lever to its original position so soon as the cam D lifts the point of the feeler high enough.

KNOWLES' CHAIN

The Knowles, Whitesmith, Cowburn and Peck, and several other four-shuttle motions, have two lifting

agents which are arranged in the proportion of 1 to 2; they work either as one or both additional, or as cancelling each other. In a device patented by L. J. Knowles in 1874 the shedding, picking, taking-up, and shuttle-box mechanisms are all connected and worked by

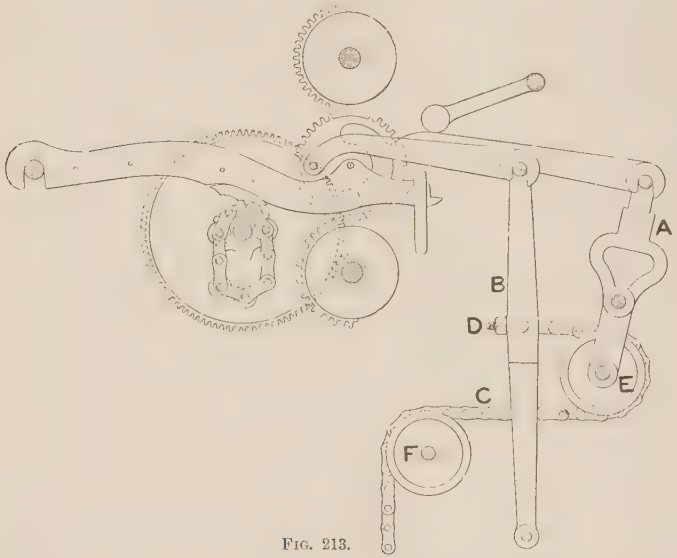


FIG. 213.

similar parts from one centre. For a description of the shedding motion see pp. 122 to 129.

In order to move four boxes, two vibrator levers, two gears, and two connectors are used. The connectors operate two levers A, B, Fig. 213: A being of the first order, and B of the second. A chain C is fixed to B at a point D; it passes round a flanged pulley E, which is suspended from A, thence over and under two or more guide pulleys F to the shuttle boxes.

By altering the relative positions of D, E, any one of four shuttles may be placed in line with a picker. In Fig. 214 the gears A′, B′ are shown in all possible positions. The top box is level when both crank pins are on the

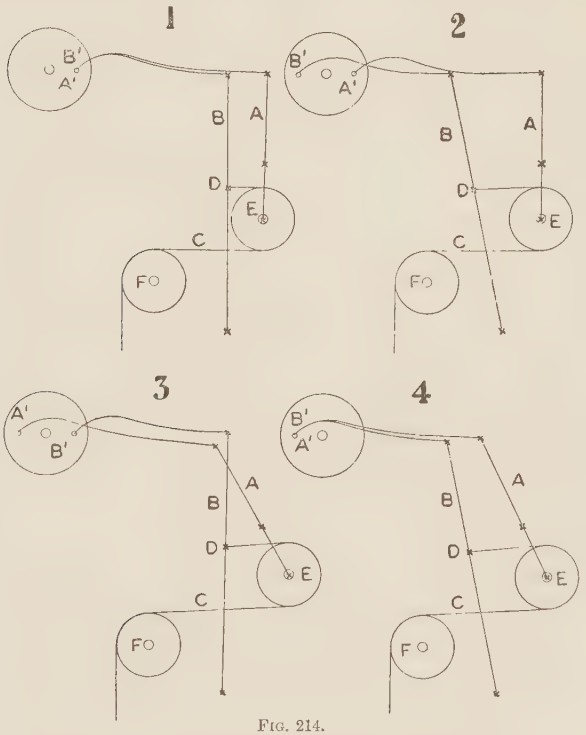


FIG. 214.

right of the centres of wheels A′, B′, as shown in division 1, for then D, E are as close to each other as it is possible to place them. By moving the pin of B′ to the left of its centre, number two box will be level, as in division 2, because the lever B has a lift of one box, ∴ box

1+1=box 2. By turning the pin of B′ to the right, and that of A′ to the left, as in division 3, number three box will be at the race board, because A has a lift of two boxes, ∴ box 1+2=box 3, also box 2+2−1=box 3. When both crank pins are on the left of their centres, as in division 4, number four box is in line with the picker, for A=2 and B=1, ∴ box 1+2+1=box 4, also box 3+1 =box 4. Six shuttles may be manipulated in a similar manner, by employing three sets of parts instead of two.

In this motion the boxes are not taken down positively, but vibration is effectively prevented by paying out the chain C slowly at the beginning and end of a change, and quickly at the centre, as is the case with movement when derived from any crank that turns from one dead centre to another. The cylinders L, M, Fig. 74, have each two sets of teeth, one for operating the shedding, the other for operating shuttle boxes and picking, the latter segments being adjustable to permit the boxes and picking to be timed differently from the shedding.

Positive Drop Boxes—Wright Shaw's

In 1857 R. Roberts and W. and S. Shaw obtained a patent for a positive box motion, and in 1889 Wright Shaw procured his last patent for the same device. Its parts are shown in Figs. 215 to 220. A cam A, with a throw equal to the lift of one box, is fixed upon the tappet shaft, and a sliding cam B, with a throw of two boxes, is connected to A, and rotated by a stud. An open coiled spiral spring is loosely threaded upon the shaft normally to hold B away from A. Either A or B constantly acts on a flanged bowl D, mounted upon a lever E; the latter is centred at F, and from its forward end a double rack G is

suspended. G, D, E, therefore, rise and fall once in two picks, and a flat spring 18′ steadies the movement when B engages D. The rack G spans a pinion H, and H is com-

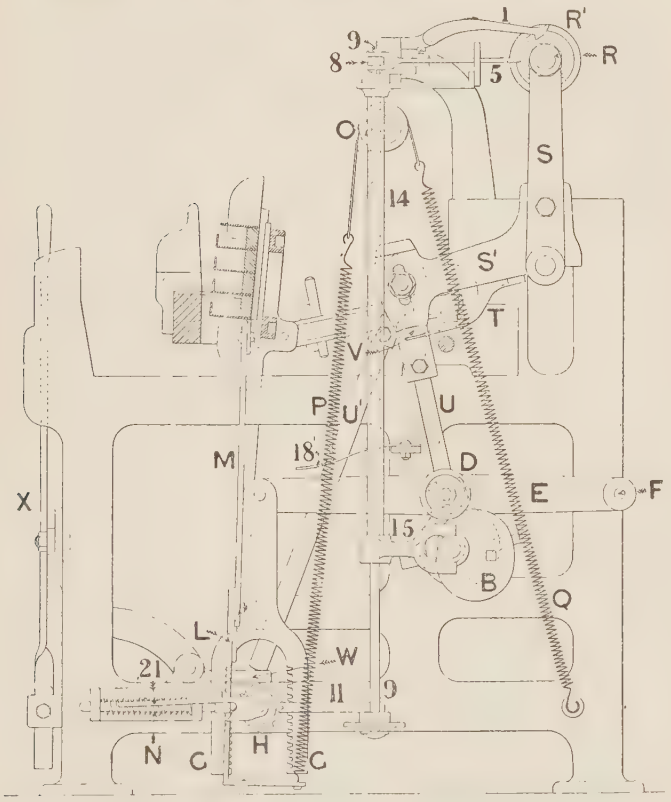


Fig. 215.

pounded with another pinion and also a disc, all of which fit loosely upon a stud. The disc is furnished with six notches, and into the upper one a spring pin fits to hold

the boxes steady. The second pinion gears into a rack L where the pitch line coincides with the axis of the rocking shaft. L forms part of the spear rod M, and both rack and pinion are kept in contact by a spring N, which is strong enough for normal conditions; but, in case of defective picking, it prevents smashes by contracting, and thus permitting the rack to disengage itself from the pinion. The shuttle boxes may be adjusted manually by lifting a handle 21, for this thrusts back the spring N and takes the rack L out of gear with its pinion. Two helical springs P, Q are used to balance the boxes; both are

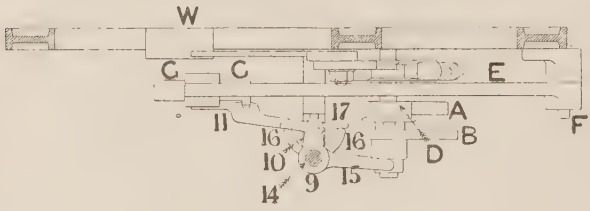


FIG. 216.

hooked into a strap that passes round a flanged pulley O, but P is connected to a bracket on the foot of rack L, while Q is made fast upon a fixed stud in the framework. When the top shuttle faces the picker both springs are stretched, and the force stored in them assists the boxes to rise.

An eight-sided card barrel R is supported on a cranked lever S, and a conditional vibrating motion is given to it by an eccentric upon the tappet shaft. The eccentric strap-rod has bolted upon it a slotted piece U, containing a lug V for the lever S to rest upon. A flat spring T is bolted to the under side of the arm S′ and goes beneath V to unite S and U. As the eccentric pushes up U, the barrel R is forced out positively; but its inward traverse

depends upon the pull of the spring T against the lug V. Hence T must exert sufficient force to carry R forward until some unusual obstruction presents itself, when the resistance of T is overcome, and U continues to descend without moving the card barrel.

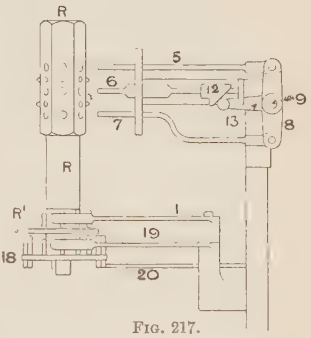


FIG. 217.

A stud on the arm S′ passes freely through a slot in U to support a flat bar U′, that terminates at the loom rail. The office of U′ is to prevent the barrel R from rotating after the weft-fork lever has acted to stop a loom. This is accomplished in the following manner: An arm W rests upon the loom framing; it is set-screwed to a sliding rod that traverses a loom, in front of the rocking shaft. At the opposite extremity to W, this rod is connected to a pattern handle X, and X is placed alongside the starting handle. When the starting handle is moved into its driving notch, a bracket upon it carries X simultaneously into a detent; but the starting handle can be removed from its notch without influencing X. This permits a weaver to turn a loom by hand. As the weft-fork lever acts, an arm thrusts X from its notch, and W is placed beneath the bar U′, to arrest the barrel R in its forward movement, before a pawl 1 can engage a stud in the lantern R′ of the barrel R, and thus prevents it from rotating.

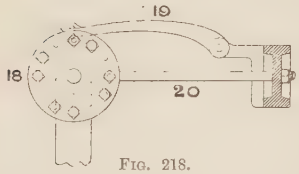


FIG. 218.

In Fig. 219 five steel cards of a pattern chain are shown.

On examination it will be found that there are only three distinct cards, for if the left end of C is laid over against the right end of D, both will correspond. Also, F and E are similar when one is turned over. Therefore, B, C, and F are the only cards necessary. They are fastened

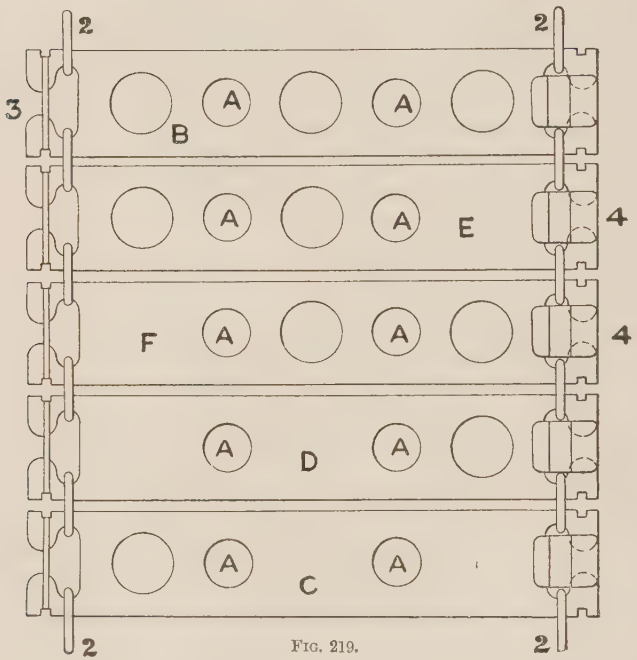


FIG. 219.

together to form a chain by placing rings 2 in suitable grooves, and holding them in position by rubber bands 3, or, better still, by the small steel clips 4, shown detached in Fig. 220. Oval rings may be used without end clips of any description. This chain is passed round the barrel R, Figs. 215 and 217, and the rotary movement

of R presents each card in succession to three needles 5, 6, 7. Needles 5 and 7 are jointed to a swivel piece 8, which is fast upon the top of an upright shaft 9. At the foot of 9 an arm 10 is hinged to a groove piece 11. The groove of the latter receives a projecting lip from the inner arm of the double rack G; therefore, if either needle 5 or 7 be pushed back, 8 and 9 swivel, and cause 10, 11 to either pull or push one of the racks G into gear with the pinion H. At the next upward movement of G one shuttle box will be taken up or down.

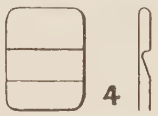


FIG. 220.

The needle 6 has a piece 12 fixed to it, and when pushed back, the inclined surface of 12 causes 14 to vibrate by acting upon an arm 13, attached to the top of a tube 14, through which the shaft 9 passes. A forked arm 15, on the base of the tube 14, takes into a ring groove in the boss of the sliding cam B, and as 15 vibrates B is pushed under the bowl D, thus imparting additional movement to the lever E, the rack G, and the shuttle boxes, presuming that either 5 or 7 is pushed back with 6. After needle 5 or 7 has been pushed back by a card, it must assume the position shown at Fig. 215. This is accomplished by causing a spiral spring to force a T-shaped hammer 17 against two curved pieces 16 on the foot of shaft 9. A similar effect is produced on needle 6 by the spring that holds the cam B out of contact with the bowl D, for this spring thrusts out the forked arm 15, and presses 13 upon the inclined surface of 12.

Two metal pegs, fitted in every face of the barrel R, pass through the small holes A of the pattern chain, Fig. 219, and hold its large holes exactly opposite the needles. When standing in a working alley facing the cards, the outside needle will enter holes on the right, and the inside

needle those on the left. A card B with three large holes effects no change. A card E with two large holes lifts one box, and F sinks one. A card C with a single large hole produces an upward movement of two boxes, and D sinks two boxes. Hence to drop a box, the inside needle is pushed back; to lift one, the outside needle is pushed back; if the middle and inside needles are moved, two boxes will drop; and the middle and outside needles will lift two boxes.

In order to economise a pattern chain, a disc 18, Figs. 217 and 218, is mounted loosely upon the axle of the barrel R. This disc has on one face twelve pegs; as the barrel moves out, one peg is caught by a pawl 19, and one-twelfth of a revolution is made. On the opposite side of 18 a series of twelve holes are tapped to receive adjustable screw pins which, as the barrel moves in, impinge against a fixed stop 20. Whenever this occurs, the lantern R′ does not advance far enough for the pawl 1 to act, consequently the barrel R does not turn, and the same card will be again presented.

If all holes in the disc 18 are empty				each card	= 2	picks.
If alternate holes are filled with screws				,,	= 4	,,
If two holes are filled and one missed				,,	= 6	,,
If three	,,	,,	,,	,,	= 8	,,
If five	,,	,,	,,	,,	= 12	,,
If eleven	,,	,,	,,	,,	= 24	,,

Shaw's mechanism may be summarised as follows: It is positive in action, and the pattern chain is stopped when a weft breaks. If the picker is not clear of the boxes, or if a shuttle is imperfectly boxed at the time a change is to be made, the spear rod disconnects itself from the driving pinion to prevent smashes. Only one box of the series can be skipped at any movement, and the card-saving appliance

is useless where two picks of one colour are required, also where the picks of any colour are not 4, 6, 8, 12, 24, or multiples of those numbers.

The Eccentric Motion

Between the years 1857 and 1870 Isaac Whitesmith introduced and developed a theoretically correct arrangement for working drop boxes positively. He compounded two or more eccentrics by placing one inside another, and moved them independently or conjointly. If two were employed, the smaller had a lift of one box, and the larger, a lift of two boxes. By suitably manipulating them, any one of four shuttles could be instantly and steadily moved to face a picker.

The value of eccentrics for this purpose is admitted by all, but the mechanisms for controlling them vary greatly. One of the best-known plans was originally patented by W. H. Hacking in 1877, but it was modified in 1889. As illustrated in Figs. 221 to 223, it controls four boxes. The parts are driven from the crank shaft by a pinion A of 18 teeth, which gears with a stud wheel B of 36 teeth. At one place in the periphery of B there are three extended teeth, and on one side a bead forms a cam, while from the centre a sleeve projects for the purpose of receiving a stud, and of carrying two slotted hoops F. A card cylinder G swings on a fixed pin and is furnished with a bowl H, that rests against the cam on B. In rotating this cam pushes the cylinder from the points of two horizontal needles, and at the same instant the three broad teeth on B take into a wheel I, of 20 teeth on the shaft of the card barrel G, and move G one-fourth of a revolution. By so doing, a series of metal cards are positively moved to

face the needles, but a spiral spring J draws them into contact.

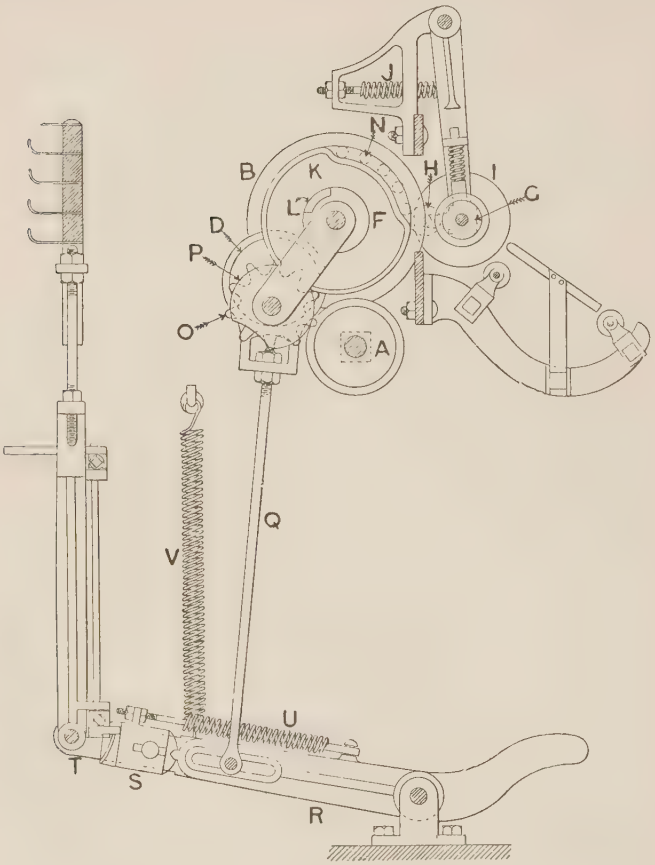


Fig. 221.

Two peg wheels K face each other and slide freely upon the sleeve of B. They are uniformly rotated by

projections L, which fit loosely in the slots of the hoops F. When the needles are inoperative both wheels are kept apart by the pressure of a spiral spring E, threaded upon the sleeve. The peg wheels can, however, be moved towards each other by the needles and two grooved cams combined; the latter are formed in the bosses M of the peg wheels K, and the former are pushed into the grooves by blank cards. Five pegs N are cast on the inside of each peg wheel to serve as teeth, and when both wheels approach each other, the pegs N drive two star wheels O. Both will be moved if a blank card is opposite each needle, but a blank opposite one needle will produce a change on that side only.

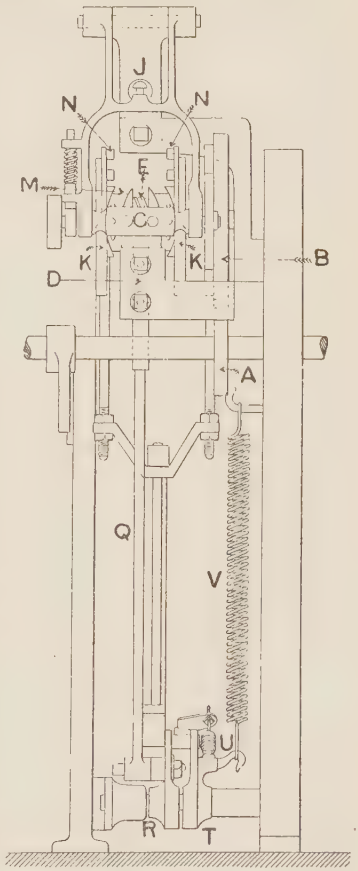


FIG. 222.

Each star wheel O has 10 teeth, and is compounded with an eccentric D, and a locking plate P. The small eccentric is loose on a spindle, the large one encloses it, and is in its turn enclosed by a

ring. On the small eccentric O and P extend outward, on the large eccentric they face the loom. A locking plate is a disc with two pieces cut from opposite edges to coincide with the full surface of a peg wheel K, hence before a change can be made a depression in the surface of K must be presented to that of the plate P. When a peg wheel engages a star wheel, its eccentric is moved from one dead centre to another; this gives a slow movement to the boxes at the beginning and end, but a quick one in the middle of each change.

A rod Q on the eccentric ring is jointed to a short lever R, having a wedge-shaped terminal fastened by a slip catch S to a longer and parallel lever T, upon which the spear rod is mounted. The slip catch is notched and free to slide upon a pin in T, but is pulled by a spring U over the wedge of R. Hence when the picking and box motions are working properly both levers move as one; in case either a picker or a shuttle is jammed in a box, U stretches, the connection between R and T is severed, and the eccentrics move without the boxes. If the pull of U is excessive, too much force will be needed to detach the boxes; if insufficient they will be liberated when they should be united, or they will not be moved flush with the race board. To enable the mechanism to work as light as possible, a spring V is hooked into the spear rod lever and upon the framing, to serve as a balance.

Fig. 223 shows the eccentrics in all possible relations to each other. The small one gives a movement of one box, the large one gives a movement of two boxes. When the top box is level with the race board, the small sides of A and B are at the top. To place the second box level, the large side of A and the small side of B must be uppermost. The third box requires the large side of B and

the small side of A to be up. The fourth box is level when both large sides are up. Or if the top box is level with the race board, by pressing back the outside needle, number two box will rise to the picking position, ∵ box 1+A=box 2, or 1+1=2. From that point number three box will be brought into range of action by operating both needles, ∵ box 2+B−A=box 3, or 2+2−1=3. From box three, box four can be reached by moving the outside needle, ∵ box 3+A=box 4, or 3+1=4. In moving from box four to box three, the outside needle must be again operated; because the eccentrics always move in the same direction, hence, if the first half of a revolution lifts a box, the second half will sink one. To place box two in position both needles must be thrust back. Box one can then be reached by moving the outside needle.

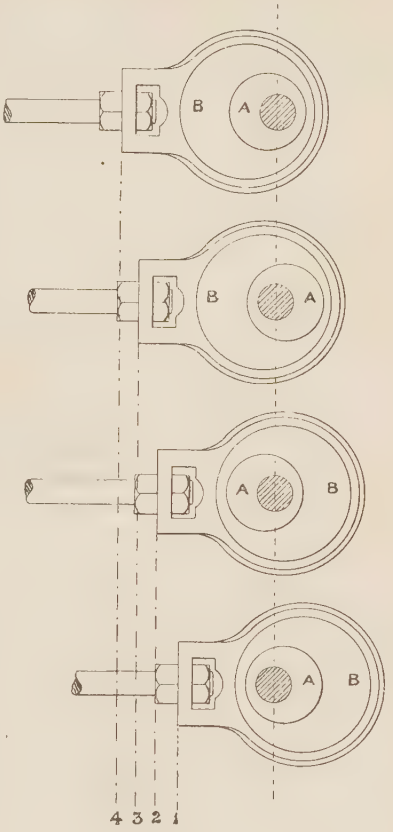


FIG. 223.

Owing to the eccentrics moving in one direction only, similar cards at different parts of a chain produce dissimilar results. For instance, a blank in a card when opposite the small eccentric needle may produce the following results :—

A change from box	1	to box	2
,,	,,	,,	2	,,	1
,,	,,	,,	3	,,	4
,,	,,	,,	4	,,	3

If a blank faces the large eccentric needle, any of the following changes are possible :

Box	1	to box	3
,,	3	,,	1
,,	2	,,	4
,,	4	,,	2

If a blank faces both needles, the changes may be from

Box	1	to box	4
,,	4	,,	1
,,	2	,,	3
,,	3	,,	2

If a hole faces each needle the boxes will not change. This makes a chain of cards difficult to read without first observing the initial positions of the eccentrics.

To reduce and increase the lift of the boxes the rod Q is respectively moved away from and nearer to the fulcrum of R. The first peg of a wheel K should engage with a star wheel O, when the cranks are on their top centres, and the first lengthened tooth of the stud wheel B should gear with the cylinder wheel I, when the cranks are similarly placed for the following pick.

Changes in the foregoing mechanism have been made from time to time. One consists in retaining only those

cards that have perforations facing both needles. Clips are then pushed over the cards to stop up the requisite holes, and thus provide for changes in the boxes. Another modification aims at reducing strain upon the needles by causing each to move a pegged segment instead of the entire peg wheel. A third change offers facilities for adjusting the boxes from the front of a loom. This is effected by lifting a light cranked lever.

The most important change was made in 1891 by W. H. Hacking, who applied parts by which similar cards always produce similar results. In working out this scheme the inventor displayed more ingenuity than was needed to produce the original motion. The additions and alterations are shown in plan and elevation in Fig. 224. Two cranked levers A are mounted upon a pin above the peg wheels K. Each horizontal arm terminates in a disc weight B, and the back of each vertical arm is furnished with a stud C that faces a cam groove in one of the bosses M. These studs take the places of needles in the previous plan. Two T-shaped pieces D are separately hinged upon the vertical arms of A, and are further supported by two spiral springs E, that impinge upon the under surfaces of D and upon a second pair of cranked levers F; two bolts, in addition to forming yielding connections, hold the springs in position. A stud L is cast upon the outside of each locking plate P, and as the plates move from one dead centre to another they vibrate the levers F. In doing this the spiral springs tilt up the heads of the T-pieces D.

The pieces D are acted upon by four needles G. A needle consists of a cylindrical pin secured at the centre of a vertical plate H. In the rear of each plate are two pins I, upon which spiral springs are threaded. The needles

are supported by passing the ends of I, I through holes in a drilled plate. In addition to the pins there are two pro-

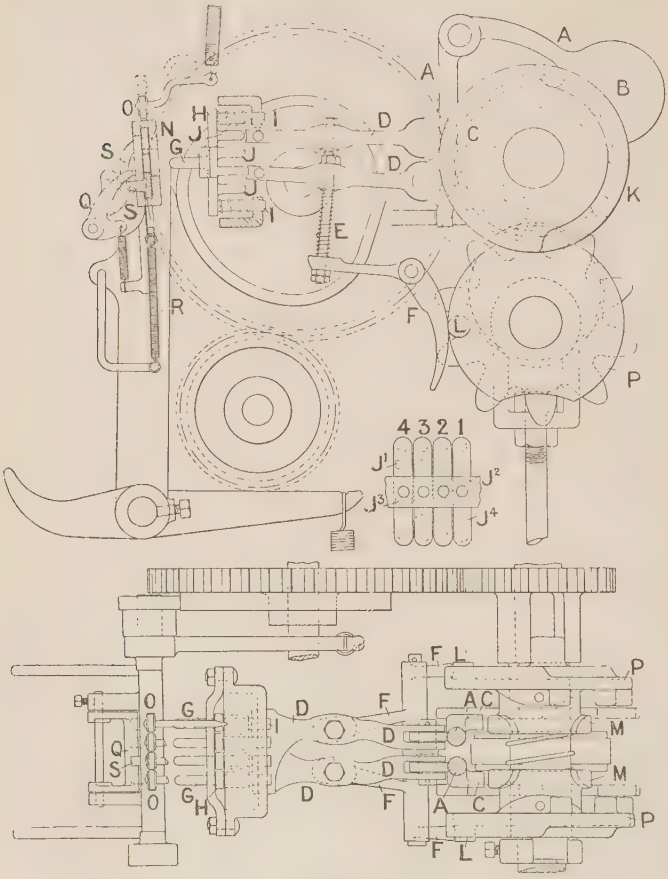


FIG. 224.

jections J at the back of each plate H, but their positions differ on every plate. Collectively they form four lines,

so that if a stud L, in the locking plate for the large eccentric, lifts the upper T-piece and a needle be pressed back, a projection J in the top line will force back that T-piece, and cause a stud C to put the large eccentric in motion. After a locking plate has made half a revolution its stud L is removed from a lever F, and the upper T-piece falls to the second line of projections, where it may again be pressed back to operate the large eccentric. The lower T-piece, if lifted by a stud L in the small eccentric locking plate, will be pressed back by a projection J in the third line; if left down it will be operated by a projection in the bottom line. Each time the lower T-piece is pressed back the small eccentric will move. The positions of the studs L upon the locking plates, therefore, control the height of the T-pieces, and the projections J upon the needle plates, together with a backward movement of the needles, cause the boxes to rise and fall.

When the top box is level, the full sides of both eccentrics are at the top, because the rod Q, Fig. 221, is behind instead of before the fulcrum pin of R; both studs L, Fig. 224, in the locking plates are at the front, and both T-pieces are lifted. Counting from top to bottom:—

Number one needle has projections J in the second and fourth lines.

Number two needle has projections J in the second and third lines.

Number three needle has projections J in the first and fourth lines.

Number four needle has projections J in the first and third lines.

Each needle, if pressed back, will always bring a box of corresponding number to face the picker.

The accompanying table shows the position of every part for every movement of the boxes.

Boxes.	Large eccentric.	Top T-piece.	Stud in large eccentric plate.	Small eccentric.	Bottom T-piece.	Stud in small eccentric plate.	Needle.
Top box level	up	up	front	up	up	front	
Change from							
1 to 2	up	up	front	down	down	back	No. 2
2 to 3	down	down	back	up	up	front	No. 3
3 to 4	,,	,,	,,	down	down	back	No. 4
4 to 3	,,	,,	,,	up	up	front	No. 3
3 to 2	up	up	front	down	down	back	No. 2
2 to 1	,,	,,	,,	up	up	front	No. 1
1 to 3	down	down	back	,,	,,	,,	No. 3
3 to 1	up	up	front	,,	,,	,,	No. 1
2 to 4	down	down	back	down	down	back	No. 4
4 to 2	up	up	front	,,	,,	,,	No. 2
1 to 4	down	down	back	,,	,,	,,	No. 4
4 to 1	up	up	front	up	up	front	No. 1

Instead of moving the needles G by cards they may be worked from a dobby or a Jacquard, in which event the card barrel and its driving wheel are removed. In their stead a flat plate N is mounted in a cradle, and rocked in the usual manner by a bead on the stud wheel. The plate N is slotted vertically in four places. In each slot a sliding shutter O is fitted to face a needle, and when O is in its lowest position a hole is presented to a needle; this equals no change. When a shutter is lifted a blank faces a needle, and produces a change in the boxes. Only one shutter can be lifted at any time, for by lifting one any other that happens to be up will automatically sink. This is effected by a lever Q whose edge is placed parallel with the shutters. Each shutter is held down by a spiral

spring R, and each is furnished with a lip S. In rising, the curved side of S thrusts out Q, liberates a lifted shutter, and the spring R draws it down. Once a lip is lifted to its proper position a spring draws Q beneath that lip, and the shutter remains suspended until the following change is made. It is the office of the dobby or the Jacquard to lift these shutters when required.

Hodgson's Box Motion

In 1893 F. Leeming and G. Hodgson introduced a multiple shuttle box motion which resembles Whitesmith's in so far that two pieces of mechanism act in the proportions of one to two, and may be employed separately or conjointly to move any box of a set of four into line with a picker. In Fig. 225 the parts are shown in plan and elevation; A is a spur wheel upon the crank shaft; B a carrier; C a wheel mounted loosely upon a stud D and containing the same number of teeth as A. The wheel C drives a boss W, in which two sliding segments E, F are fitted. A fork G, fixed upon a shaft H, enters a ring groove in E. A similar groove in F receives a fork I, attached to a shaft J. If a lever K, on the shaft H, be lifted through the medium of a dobby or a Jacquard, the fork G will move the teeth of E to face those of a star wheel M, and M is compounded with a disc crank N, whose throw gives a lift of one box, namely, the throw equals half a box and the leverage of S gives the other half. By lifting the lever L, on the shaft J, the teeth of F will face those of a star wheel O, also compounded with a disc crank P, but the throw of P gives a movement of two boxes. Both M, N and O, P rotate upon studs X bolted to the framing. A connecting rod Q is attached to the crank pin of N, and at R to the

spear rod lever S. Another connecting rod U, mounted on

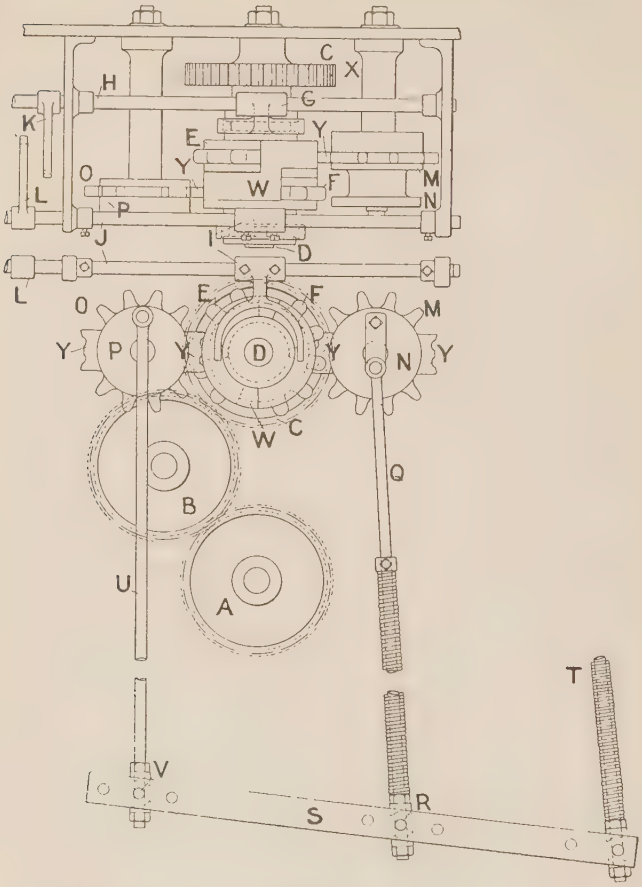


FIG. 225.

the pin of P, is united with S at V. The spear rod T is also attached to the same lever. In the event of a shuttle or

a picker becoming jammed, one spiral spring on Q and another on T furnish escapements for upward and downward movements in the boxes. As a crank N or P moves, V and R respectively become the fulcrum of S. But when both cranks move together no part of S is stationary, yet by reason of the small throw of N, R becomes the fulcrum.

A crank N or P when moved by the rotating segments E or F passes from one dead centre to another, and always in the same direction. Yet a like card in a box chain will always bring the same shuttle to face a picker. This arises from forming the teeth of each star wheel M and O in two sections, one section being in a different plane from the other, so that when the levers K and L are unlifted one line of teeth in M, O face those in the sliding segments E, F. Also, when K, L are lifted the other line of teeth in M, O face those in E, F; but in each case half the periphery of M, O is plain. If the teeth in M or O are on the driving side of and facing those in E or F, the former will make half a revolution and the boxes will change, but after the first movement, and with the levers K, L unaltered, the blank portions of M, O will face the teeth in E, F, and the boxes will be stationary. Each segment has a portion of its last tooth cut away to enable it to engage with a recess in the sliding pieces E, F. When stationary both cranks are locked by the curved surfaces Y, which coincide with the surface of W.

Cowburn and Peck's Motion

In 1888 and 1889 J. Cowburn and C. Peck introduced a motion in which Whitesmith's principle forms the central feature, but instead of using eccentrics they employ a double crank and two discs. Each disc, A, D,

Figs. 226 to 229, is free to turn on a stud in the framing, and each has a pinion A′ formed on its boss. The outer disc D carries a stud that gives a throw of one box. On this stud a crank C, with a throw of two boxes, is loosely fitted, and its pin passes freely through a slot in the disc A. The crank C supports an arm E, which is made in two pieces and hinged to the spear rod lever F. Two flanges on E are drilled to receive a rod E′; the latter is screwed to take two adjusting nuts, and a spring threaded upon it impinges against a shoulder on E′ and a flange on E. In case a picker or shuttle is trapped as E moves down, the spring contracts, and a smash is prevented. Similar connections on the spear rod provide for a similar contingency as E moves up.

A cradle G is rocked on a stud by an adjustable crank H and a connecting rod I. At the outer end of G two racks J, K are centred to fall from the disc pinions A′ by gravitation, and rest against the rear ends of two horizontal needles L, M, Fig. 228. A blank card in pushing back a needle causes a rack to engage a disc pinion, hence the disc's motion depends upon that of the rack; and since contact is only made as the racks descend, a disc always moves in one direction, and through exactly half a revolution. This carries the crank pin or the crank C from one dead centre to another. When not in action, each disc is locked by a flat spring that forces a catch N into the uppermost of two notches cut in the disc's rim. Vibration is thus prevented until a change is to be made. As a needle recedes from a blank card, it bears on the base of a catch N and lifts its upper end clear of a notch in A or D.

A four-sided card barrel O has a star wheel Y fixed on one end of its shaft. O is mounted upon the top of a

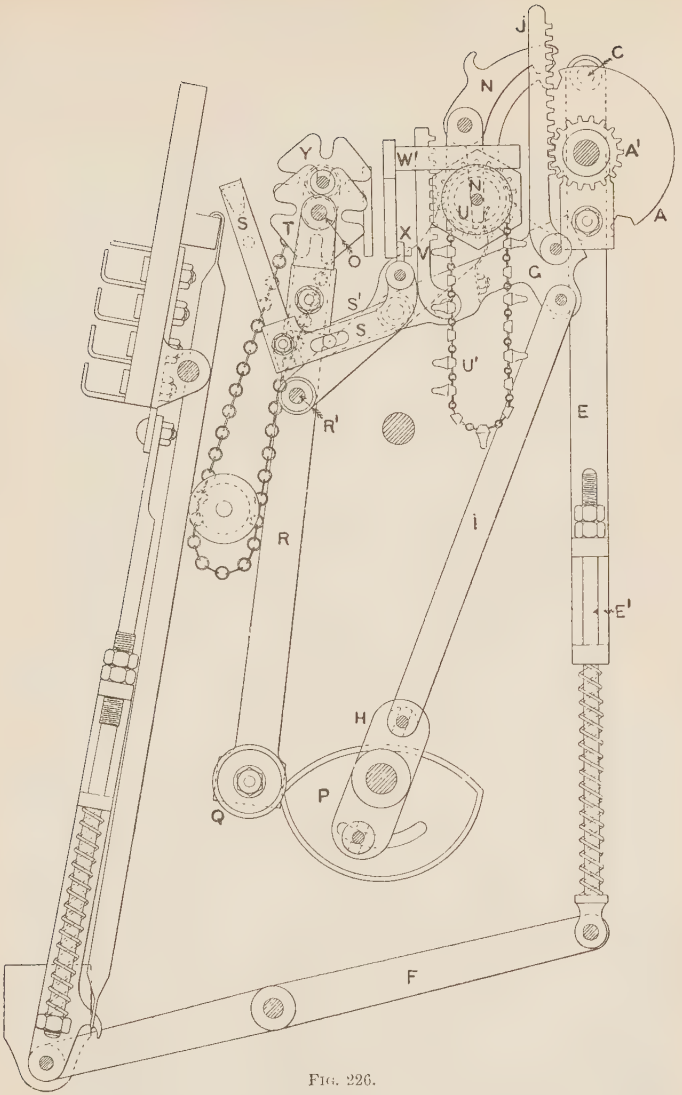


FIG. 226.

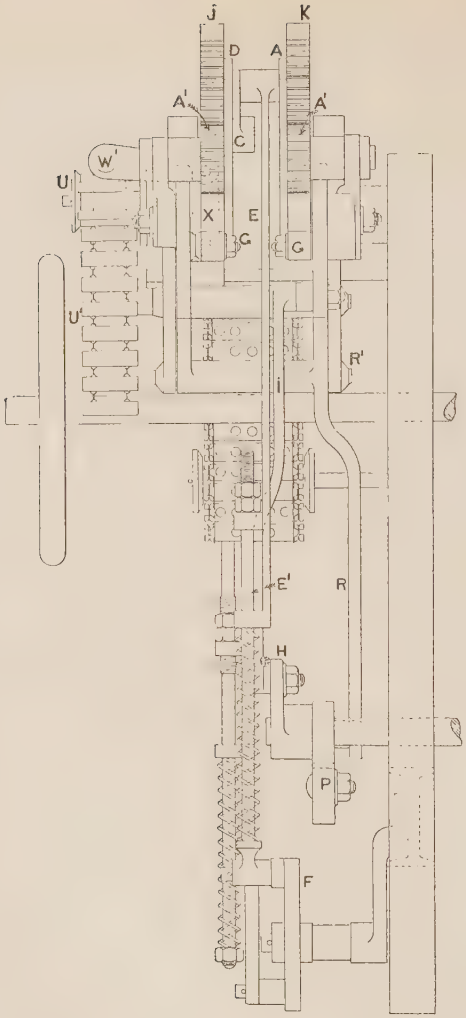


Fig. 227.

bar R, which is centred on a stud R′. At the base of R a bowl Q rests against the cam P upon the bottom shaft. The barrel O is rotated by one of two pins in an L-shaped pawl S, that engages the notches of a star wheel Y or T. The necessary vibrating movement is given to S by

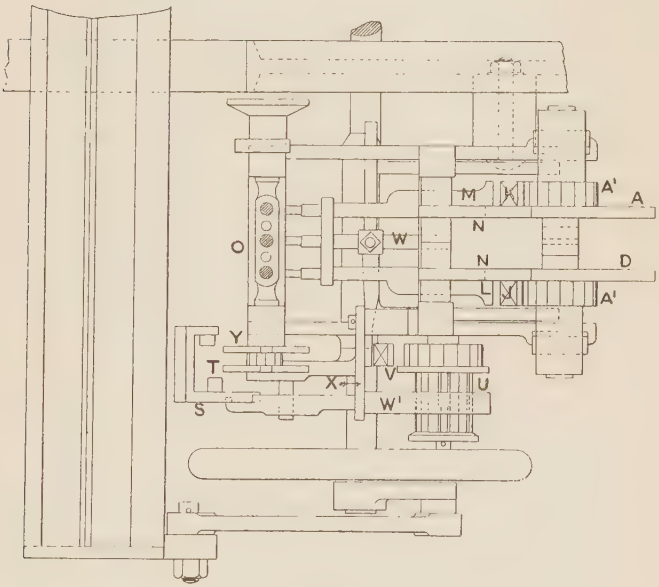


Fig. 228.

keying an arm S′, Fig. 226, upon the axle of the cradle C, and passing a pin from S′ through a slot in the lower arm of S.

Any box can be moved to the shuttle race as follows:— When the stud and the crank C are on their top centres, the top box is in position. When the stud is turned down and C left up, number 2 box is level. When C is down and

the stud up, number 3 box is level, and by turning the stud and C upon their bottom centres, number 4 box will be level with the race board.

A link-saving motion is a feature of this invention. It consists of a hexagonal lattice barrel U, round which a chain of wooden lags U′ is passed. The lags have either raised or flat surfaces, the former being equivalent to pegs, the latter to blanks; they are alternately raised and flat, except for scarves and handkerchiefs, when two consecutive raised or two flat lags are necessary at two places to carry the pattern chain forward from the middle to the border cards, or *vice versa*. Since a raised lag followed by a flat one reverses the direction of a pattern chain, it thus becomes possible to weave long patterns with few cards. Lags of medium thickness are also used; in such cases their surfaces are sufficiently raised to move both pins of the pawl S out of contact with the star wheels Y, T. The barrel O then ceases to rotate, and the same card of the pattern chain is presented to the needles on two successive vibrations of O.

The barrel U is only moved when a pattern chain has to be reversed, or when one card has to be presented to the needles twice; this is accomplished by causing a third rack V to engage a pinion wheel upon the inner end of U, whenever the middle needle W is pushed back by a blank card. The rack V is also rocked by the cradle G. A cylindrical bar W′ is parallel with the needles, and rests upon a lag; it is bolted to a cranked lever X, and as the lags lift W′ the vertical arm of X imparts a lateral movement to the shaft of the pawl lever S, and so takes the upper pin out of gear with the star Y, and puts the lower pin in gear with the star T. The star T is connected to the chain barrel O by pinions, one on the barrel shaft,

the other on the boss of T. As a sequence the barrel O will turn in one direction if Y drives, and in the other direction if T drives.

Medium lags are required when it is necessary to reverse on two picks, or any multiple of 4+2 picks. For example, take the following pattern :—

6	picks of white
4	„ „ indigo
2	„ „ red
2	„ „ sky
2	„ „ red
4	„ „ indigo
20	

Assume that card one, at the top of Fig. 229, will carry the bottom box level with the picker, and that the shuttles are filled as follows :—

No. 4 = white weft
„ 3 = indigo „
„ 2 = sky „
„ 1 = red „

Card 1 = box 4 level = 2 picks of white, with a flat lag on the top of the lag barrel.

Card 7 = box 4 level = 2 picks of white, but the lag barrel has changed to a medium lag = card 7 repeated.

Card 7 = box 4 level = 2 picks of white, and a change to a full lag.

Card 1 = box 3 level = 2 picks of indigo, and no change in the lag barrel.

Card 8 = box 3 level = 2 picks of indigo, and no change in the lag barrel.

Card 3 = box 1 level = 2 picks of red, and no change in the lag barrel.

Card 2 = box 2 level = 2 picks of sky, and the barrel changed to a medium lag.

Card 2 = box 1 level = 2 picks of red, and a change in the barrel to a flat lag.
Card 3 = box 3 level = 2 picks of indigo, and no change in the lag barrel.
Card 8 = box 3 level = 2 picks of indigo, and no change in the lag barrel.

20 picks

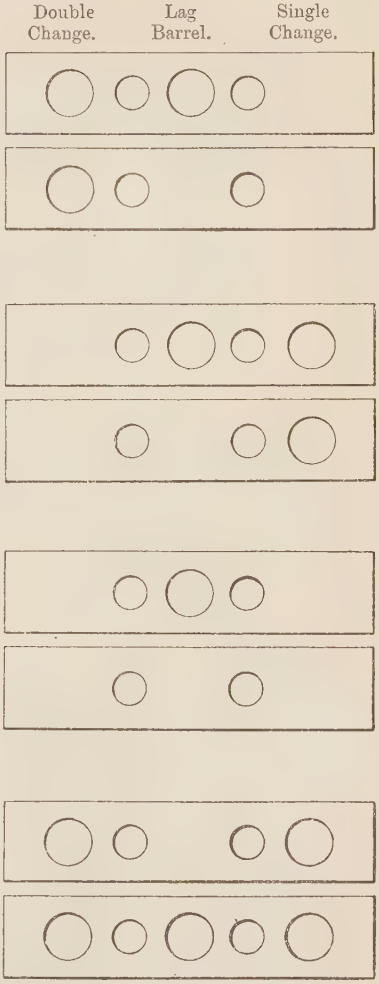
This motion is usually made for four shuttles, and the difficulties experienced in laying and reading a pattern chain are clearly shown in the accompanying Fig. 229.

Revolving Boxes

Circular boxes were invented by Luke Smith in 1843; they are now in extensive use in many branches of the textile industry. The shuttles are arranged in chambers formed in a wooden cylinder, which is moved forward or backward as required to take each shuttle into contact with the picker. Those with six compartments are in general use. In many cases the maximum movement equals one shuttle, but some are capable of skipping one or two shuttles.

The cylinder A, Figs. 230 and 231, is supported by a semi-hoop B at its inner end, and by a spindle C at its outer end. Upon C a disc D is fitted, which contains a similar number of equally spaced pegs to the compartments in a cylinder. A star wheel E is also fitted upon the spindle, so that a spring hammer by pressing against the under side of E will hold the boxes true. Two drawing hooks F, G are forced by flat springs H into contact with the pegs of D and engage them at opposite sides of the disc. F and G are centred on two bent levers I, each having at its rear end a vertical hook J which is passed through a slot in a

Cowburn and Peck's Cards for Four Boxes



From No. 1 box to No. 2 box.
" " 2 " " " 1 "

" " 3 " " " 4 "
" " 4 " " " 3 "

This Card works the Boxes, as above, and at the same time acts upon the Lag Barrel.

From No. 1 box to No. 3 box.
" " 3 " " " 1 "

" " 2 " " " 4 "
" " 4 " " " 2 "

This Card works the Boxes, as above, and at the same time acts upon the Lag Barrel.

From No. 1 box to No. 4 box.
" " 4 " " " 1 "

" " 2 " " " 3 "
" " 3 " " " 2 "

This Card works the Boxes, as above, and at the same time acts upon the Lag Barrel.

This Card makes no change in the Boxes, but acts on the Lag Barrel.

This Card makes no change either in the Boxes or the Lag Barrel.

Fig. 229.

lever K and another in L. The lever K is oscillated on a pin by causing a cam M on the bottom shaft to act upon a bowl N. At O a knuckle joint is formed in K, and a

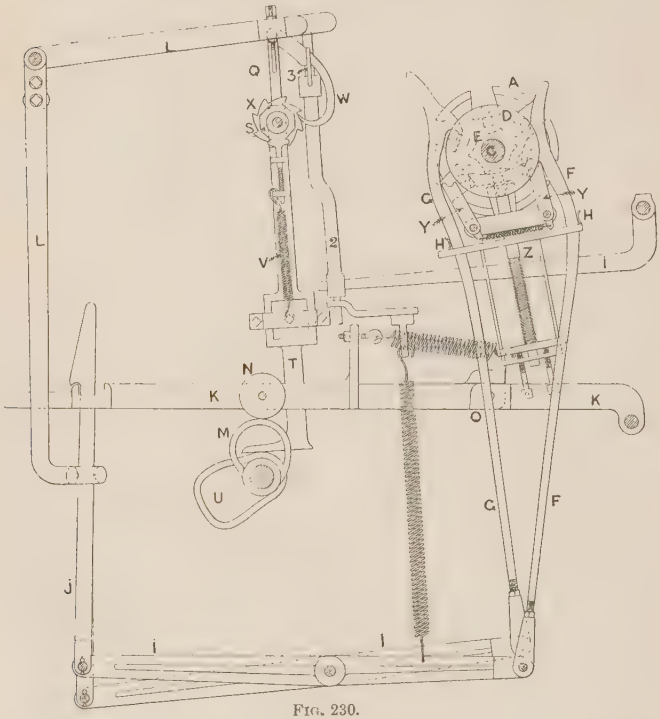


Fig. 230.

spiral spring is stretched above it to keep the lever straight until a shuttle is trapped; the joint then gives way and prevents a smash. The foot of an L-shaped bar T rests upon a cam U, but its head supports an octagonal card barrel S. The full part of U lifts T, S, but a spiral spring V pulls them down; a spring hammer meanwhile

keeps S steady. A catch W is hinged upon the framing to engage a ratchet wheel X on the barrel shaft and cause S to make one-eighth of a revolution each time T and S move down.

A feeler Q is attached to each cranked lever L, and when S is in its highest position a blank card causes L, L to vibrate and thrust back both hooks J from the solid part of the lever K. In its next upward movement K misses the hooks J, and the boxes remain unaltered. But one hole in a card leaves a feeler Q undisturbed; a hook J is then left over the solid part of K, and when K ascends it will take J with it. By this means the rear of I rises while its forward end falls and a hook F or G turns the boxes.

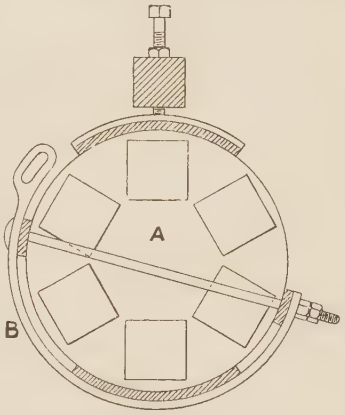


FIG. 231.

The parts I, J, L, Q being duplicated, whether the boxes move forward or backward will depend upon which cranked lever L is actuated. At half the lift of the levers I, the pins that connect them with the drawing hooks F, G should have their centres coincident with the centre of the rocking shaft, or the boxes will not move at a uniform speed in both directions.

A spring hammer cannot prevent shuttle boxes from moving too far, hence a stop of some kind is added. A stop may consist of two detents Y, each mounted on a

pin placed beneath, but at opposite sides of the boxes; in which event a helical spring Z is employed to pull both detents apart at the top. The detents Y rest against the inner curves of the drawing hooks F, G, until one of the latter is brought into operation, when one detent is thrust under a peg on the disc D, to stop further movement in the boxes.

A means for preventing a pattern chain from moving after a weft has broken is found on most revolving box looms. It consists in fitting an arm 1 upon the finger rod of a taking-up motion; 1 passes through a slot in an upright piece 2, and 2 holds a bar 3 beneath the levers L. When a weft breaks, the arm 1 lifts the bar 3 and the cranked levers L to put the hooks J out of action, thus preventing any change in the boxes. Curved plates are fixed at each end of the boxes to hold all shuttles in position until they are again required, and two cone-shaped rollers push forward the outer tips of such shuttles as the boxes turn. Without some similar contrivance boxes could not be moved at all times.

Compared with drop boxes, the advantages are, that an increase in the number of shuttles does not necessitate a decreased speed in a loom, for the movement being rotary, the weight on one side of a cylinder balances that on the other side, and the power required to move it is fixed, or nearly so. Since there is no rebound, high speeds are practicable. They have, however, disadvantages that to some extent counterbalance the advantages. In the first place, a loose reed is general, because a stop-rod finger and swell act on the front or back of a shuttle, whereas in a revolving box the shuttle top is presented where a finger would act. In such looms stout cloth cannot be economically made. Unless the checking apparatus acts

suddenly, and with certainty, boxes tend to move too far. If the boxes constantly revolve in one direction the wefts are partially twisted, and there is a risk of drawing a portion of a wrong weft into a shed with the correct one.

In 1890 A. Sowden made use of a fast reed by causing an incoming shuttle, as it thrusts back the picker, to tighten a strap attached to a lever, and thereby lift the stop-rod blades above the frogs. A cranked lever has also been secured in each box chamber, in such a manner that an incoming shuttle causes the lever to vibrate, and act, through other levers, upon the stop-rod blades.

Revolving Boxes that Skip

Revolving boxes are made to change instantly from one compartment to any other of a set of six. This has been accomplished by various mechanical devices, but the one generally adopted was patented in 1869 by R. L. Hattersley and J. Hill. It consists in positively moving a revolver by one of three cams, which operate separate griffe levers, separate hooks, one bottom lever, and a duplex rack similar to Shaw's, see p. 405. When necessary the rack engages teeth on either side of a spur wheel fixed upon the revolver axis. The cams respectively move a revolver one, two, and three compartments. Any of these changes may be made by a box chain, a dobby, or a Jacquard acting upon the usual cranked levers. A fourth cam, with its complement of levers and hooks, determines the direction of movement in the revolver, and unlocks and locks it before and after each change. When a box chain is used, a fifth cam rotates the card barrel of an indicating apparatus, and moves the feelers away from, and into contact with the cards.

The details of this device are shown in the accompanying Figs. 232 and 233, where B, C, D, E, F are a series of cams fitted upon the picking shaft A. On alternate picks the outside cam B may give a movement of one shuttle; the second, C, may skip two shuttles; while the third, D, may skip one shuttle. These cams act through antifriction bowls H, upon three griffe levers G, which are severally jointed upon a pin I. At J, Fig. 233, the first griffe lever G^1 has two flanges on the inside; the second, G^2, is slotted; and the third, G^3, has two flanges on the outside. The flanges and slot support three vertical hooks K, all jointed upon the first bent lever L^1. A pin N, Fig. 232, unites the forward end of L^1 to the base of a double rack M.

A spur wheel O is fixed upon a revolver spindle, and enclosed by the rack M, but the teeth of M do not engage those of O until the cam E, acting upon the griffe lever G^4, lifts the hook K^5, or K^6; the latter then pulls or pushes one rack M into gear with O. The griffe lever G^4 has two flanges on the outside, and also two slots; it operates the hooks K^4, K^5, K^6. Hook K^5 is jointed to the bottom lever L^3, and at the opposite end L^3 carries a connecting rod P. On the top of P a lever Q, with an open step formed upon it, works against the lower half of the boss of wheel O. The lever Q is provided with two projections R which fit inside smooth flanges upon the rack M. A second lever S is hinged upon the box frame, and its rear end is pulled up by a spiral spring T. It is the office of S, T to support the lever Q, but to yield whenever the latter is moved by the rod P. By drawing down P, a projection R will engage the front rack with the driving wheel O, and the revolver will be moved forward when M descends.

The inside bottom lever L^4 moves upon a pin U in

the loom framing, and the hook K^6 is jointed upon it. A stud V in L^1 takes into a slot in L^3; hence, hook K^6, acting through the lever L^4, will reverse the action of

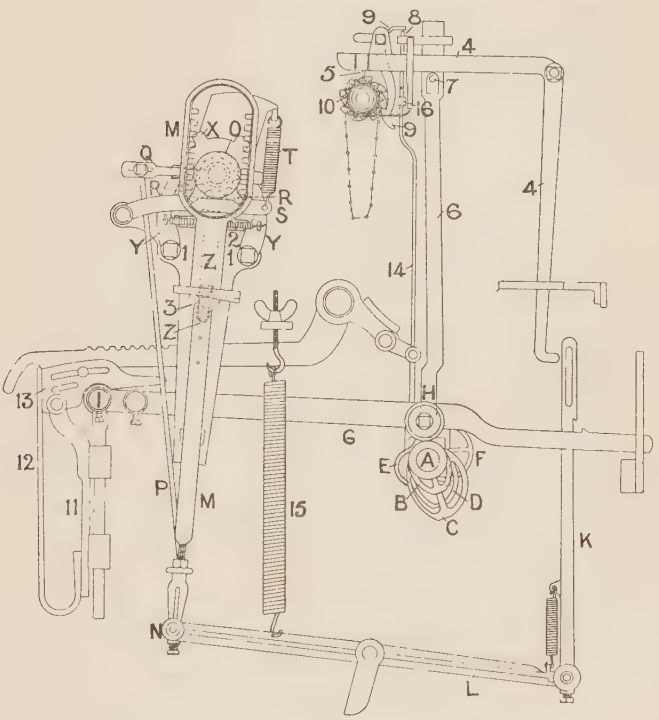


FIG. 232.

hook K^5 upon the lever L^3, and lift P, Q until a projection R engages the back rack with the spur wheel O; this causes the revolver to be moved backward when M descends.

Whether backward or forward motion be required, the rack and spur wheel remain engaged until the full distance

has been turned; but excessive or insufficient movement is prevented by a star wheel, two locking detents, and a hammer. Momentum is arrested at the proper place as follows: A star wheel X with one tooth for each shuttle compartment is fixed upon the box spindle adjacent to the wheel O. Two detents Y, fulcrumed upon studs in the box frame at 1, 1, and connected by a lateral spring at 2, draw the free ends of Y into contact with the teeth on X. Sufficient movement is ensured by placing between the detents a hammer Z, so shaped that when depressed it opens the detents to clear the star wheel. The shank of Z has the usual vertical spring at 3 to furnish an upward pressure and is jointed upon the forward end of the lever L^2. The head of Z, by engaging a projection upon X, completes the movement of the revolver. The hook K^4 passes between the flanges on the griffe lever G^4, and governs the lever L^2. Near the top of K^4 a finger W projects across the hooks K^5, K^6, so that neither can be moved outward without putting hook K^4 into operation. K^4 will, therefore, unlock the boxes by withdrawing the hammer Z and the detents Y from the star wheel X.

Five cranked levers 4 have their vertical arms in contact with the hooks K^1 to K^5, and each horizontal arm is provided with a feeler 5 for cards to operate when required. An upright bar 6 holds a stud 7 beneath the horizontal arms of 4 and is lifted by a cam F. As 6 falls the feelers 5 drop upon a card; if upon a blank, no effect is produced, but if into a hole, a revolver will move. When the bar 6 rises, the card barrel 10 is turned by a catch 9 jointed upon a lever 8, and a finger on 8 covers the fourth and fifth crank levers; hence motion in 8 is imparted through 4. The direction of motion

in a revolver, together with the unlocking of the boxes, is determined by the position of a hole in a card. If a hole is beneath the fourth feeler, the boxes will

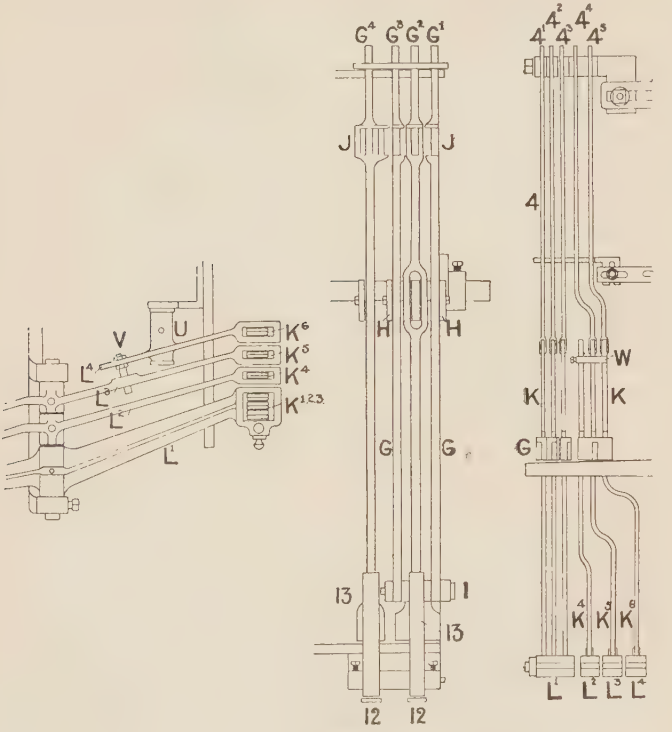


FIG. 233.

move forward, if beneath the fifth, they will move backward.

In case a picker or a shuttle fails to act correctly, breakages are prevented by mounting two cross heads 1 upon the vertical stud 11 : the first head forms a fulcrum

for the griffe levers G^1, G^2, G^3, and the second for lever G^4. Under ordinary circumstances a flat spring 12 bears upon a cap 13 with sufficient force to hold down the fulcrum I, but 12 is weak enough to permit 13 and I to rise when the rear ends of levers G^1, G^2, G^3 are prevented from moving. If cards are employed to control the mechanism, changes from one compartment to another cannot be made after a weft has broken, for a rod 14 unites an ordinary brake lever with the rear arm of the catch 9. Thus, immediately the brake is applied, the rod 14 rises, thrusts back the catch 9, and a finger moves the crank levers away from the barrel 10, hence, no matter what card is uppermost, the boxes do not rotate.

The operation is as follows: In order to move one compartment forward or backward, a hole in a card, beneath the first feeler 5, will cause the crank lever 4^1 to push the first hook K into gear with the griffe lever G^1, and G^1 will be operated by the first cam B. Before this can be done, however, the rack M must be placed in contact with the spur wheel O, the hammer Z and the detents Y must also be drawn from the star wheel X. Hence, a hole in a card beneath the first feeler must be accompanied by a hole for the fourth or fifth feeler, according to the direction a revolver is to move. If a hole is under the fourth feeler, the cam E, which is set a little in advance of cams B, C, D, lifts hook K^5, pulls down the connecting rod P, and the lever Q, and the rear projection R draws the front teeth of M into gear with the spur wheel O; the rack being securely held until a forward change is completed. Meanwhile, the hammer Z is withdrawn from the star X and its extremities hold open the detents Y until the rack has almost completed its movement; the springs 3, 2 then cause Z and the free

ends of Y to engage the teeth of X. When the rack M is released by the cam E from contact with O, a strong spring 15 lifts M into its normal position. If a revolver is to move backward, a hole under the fifth feeler will act upon L^4, and by reason of the position of its fulcrum, and its connection with L^3, the rod P will cause the front projection R to engage the back teeth of M with the spur wheel O.

In order to move two compartments forward or backward, place a hole in a card beneath the third feeler 5; it will cause the third hook K to engage L^1, and cam D will depress the rack twice as far as when operated by cam B. To move three compartments in either direction, a hole beneath the second feeler 5 will cause hook 2 to engage with L^1, and cam C will depress rack M the required distance. In all cases a hole beneath the fourth or fifth feeler will cause the finger W to be pressed back far enough to engage hook K^4 with the griffe lever G^4 and unlock the revolver.

In looms of recent construction, several cams, griffe levers, and hooks are dispensed with. One cam, one griffe lever, two hooks, and a lever compounded with the bottom lever, are employed to effect all movements in the revolver. The first hook when lifted moves the revolver one compartment, the second moves two compartments, and if both hooks are lifted together they move three compartments. The usual locking and reversing gear is retained.

PART XV

SWIVEL-WEAVING

Swivel-weaving produces small figures in extra weft upon piece goods of indefinite width; it is relatively to picking, what lappet weaving is to shedding. Both methods give a fabric an embroidered appearance, and both prevent waste, by using figuring material only where figures are made. For variety of detail, and general excellence of workmanship, swivelled fabrics are superior to lappets, but the latter are more economical to manufacture. Each pick of swivel weft is placed above a pick of ground weft; hence the length of fabric produced in a given time is determined by the number and closeness of the ground picks inserted. These fabrics have been made in power-looms for many years, but they are still chiefly produced in hand-looms. The number of shuttles in use, the elaborate mechanism required to manipulate them, and the absence of detectors to stop a loom when a figuring thread breaks, increase the weaver's work, and entail frequent stoppages of the machine.

Swivel-weaving consists in so applying small-ware shuttles to an ordinary loom that they may be lifted above the upper warp line, dropped upon the race board, and moved through the warp at pleasure. But the space between adjacent figures has been governed by the size of the swivel shuttles and the appliances employed to give them motion, and this varies from 1″ to 5″. There

is, however, an attachment on most looms by which figures may be equally distributed. The shuttles and their holders are capable of being moved laterally to place a second line of figures midway between those of a former line. Or they may be moved to form diagonal or other schemes of distribution. In power-looms, swivel shuttles are fitted in a carrying frame attached to the front of a slay, and this is raised and lowered by the indirect action of a Jacquard. By leaving cards blank at suitable places, all parts of the swivelling mechanism will remain inoperative. By suitably perforating cards the frame may be dropped upon the race board, the picking motion may be put out of action when the swivels are to move, and the long racks operated to drive the small shuttles.

In Fig. 234 a swivel shuttle is shown at A in plan, and at A′ in end elevation. It is made of wood and hollowed out in the centre to hold a spool B. This spool is loosely mounted upon a pin, one end of which is straight, the other end bent at right angles. The straight end enters a hole in one side of A, the bent end is pressed into a groove in the opposite side. A spring bears against the centre of B to prevent the weft from unwinding too freely, and an eye is formed in the shuttle at A″. Two glass rings are secured to spiral springs fixed on opposite sides of a shuttle eye. Weft is threaded through both rings and through the eye; the springs regulate tension and prevent loops from forming round the edges of a figure. A more perfect tension results from mounting a collar loosely upon a spindle, then attaching one end of a spiral spring to the collar, and passing its remaining end through a hole in the spindle. A sleeve, with four protruding flat springs, covers the spiral and fits tightly upon the collar. The spool is passed

over the sleeve and lightly pressed by the flat springs.

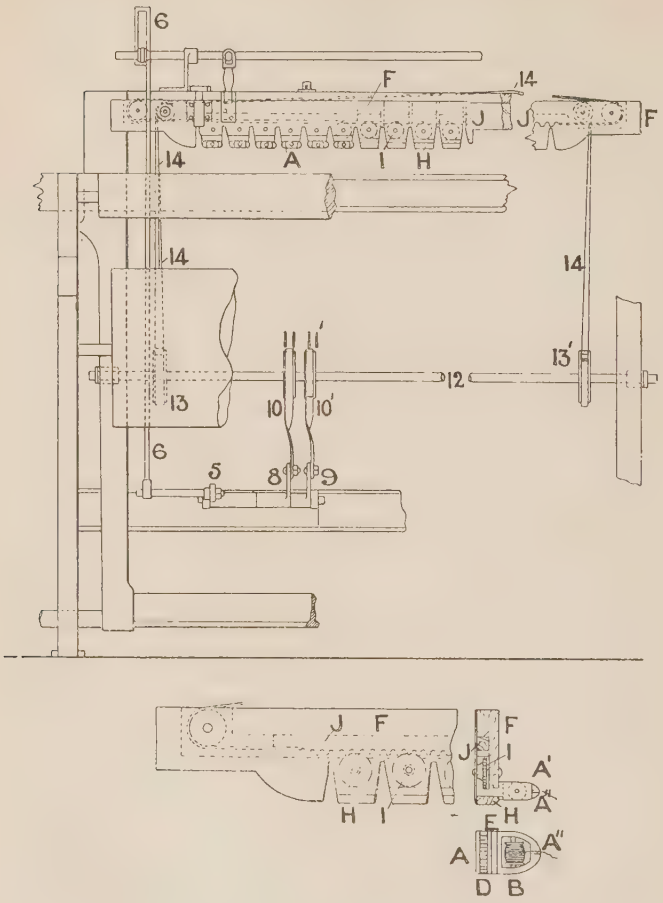


FIG. 234.

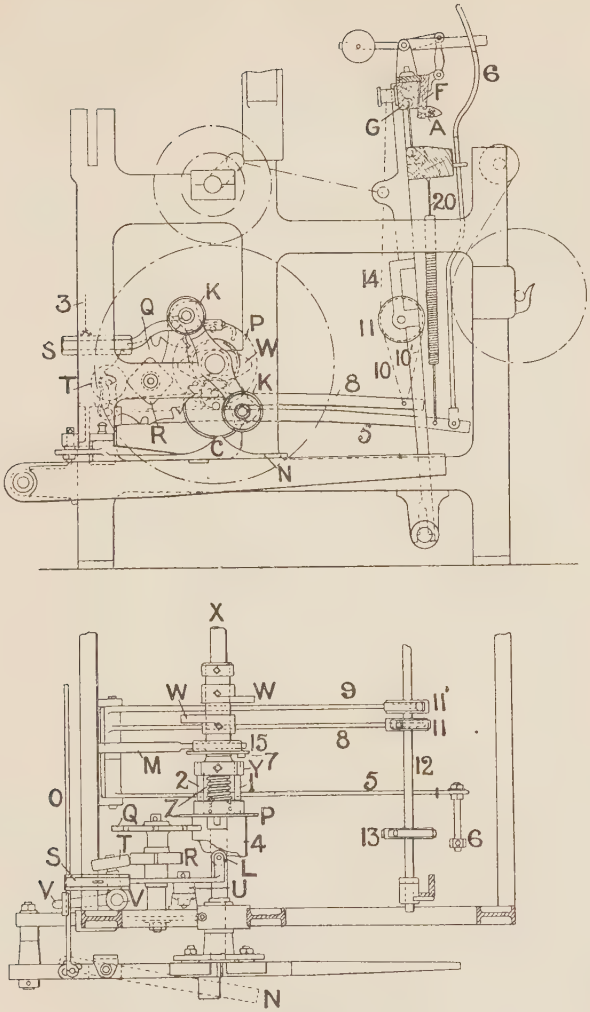
If weft is drawn away in excess of requirements, the spiral exerts sufficient force to rewind four to five inches.

A rack D, consisting of metal or leather teeth, is secured in a groove formed in the upper edge of A. In front of D a groove E is cut parallel with D to receive a lip on the swivel frame F. This frame extends across the reed space and rests against the slay cap G, Fig. 235. Behind F a thin metal plate is fixed; at its foot a support H is provided for the under side of each shuttle. These supports are detached, and the plate F is slotted in order that warp threads may be lifted between the shuttles A when the latter are upon the race board. F also carries axles for a series of pinions I, which are placed over the shuttles so that their lower teeth may engage those in the shuttle racks D; while the upper teeth in I take into a rack J that also extends across the reed space. J is free to move to and fro longitudinally, and in so doing it puts in motion the pinions I and the shuttles A. If J moves to the right, the shuttles will be driven into adjacent holders on the left; and by reversing the direction of motion in J, the shuttles will be restored to their former positions. The number of holders, therefore, must exceed that of the shuttles by one.

So long as a loom is weaving ground texture only, the swivel mechanism is inoperative, but the frame F is lowered for the first swivel pick, and the rack J drives each shuttle across the gap that separates one from another. The frame F is then raised and a pick of weft from a ground shuttle is passed through the texture. This is followed by the descent of F, and the swivel shuttles in moving through a second shed are restored to their first positions, when the frame is again raised. The process is repeated until a set of swivel figures is completed. Before the frame F is lowered for the first pick of the next set of figures, it is moved a certain

distance endwise to place the shuttles in the required positions. After those figures are completed the frame is moved back again; hence alternate sets of figures are woven in the same longitudinal line.

There are several plans for effecting the various movements enumerated above. That illustrated in Figs. 234 and 235 was developed, between the years 1890 and 1896, and patented by W. T. Birchenough and A. Wood. The ground shuttle is controlled by mounting a star wheel Q, Fig. 235, upon a stud and actuating it by a peg wheel P. The star wheel may be compounded with a barrel and chain which, by means of connections R, S, T, U, V, and O, act upon each picking lever N to bring the required nose C under the picking bowls, see Figs. 184, 185, 186. Instead of a barrel and chain the star wheel Q may be compounded with a four-winged cam R, that acts upon a bowl T fixed on a cranked lever V; the remaining arm of V being passed through a slot in the bar O. In vibrating, V moves the picking plates in and out of action. The peg wheel P is free to slide longitudinally upon the picking shaft X. It is rotated by securing two studs, 1, 2, upon its inner face and causing them to enter corresponding holes in a disc Y, which is fast upon the picking shaft. The swivel motion is controlled as follows:—A lever S is fulcrumed at U to the framework and has a cord 3, from a spare hook in the Jacquard, tied upon its weighted end. As the rear of S rises, a bowl L, at the front of S, bears upon a cam face 4, formed on the boss of the peg wheel P, and takes the pegs out of contact with the star wheel. But L also thrusts a projection from P against a bowl on a lever 5, whose office is to draw down a slotted rod 6, and thus permit the swivel frame F to fall by gravity. As P continues to slide, the studs 1, 2 pass through the


6
F
G
A
20
14
11
10
10
8
5
3
Q
K
P
W
S
T
K
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N
X
W
W
9
11'
11
15
8
M
Y
7
2
5
12
0
Q
Z
P
T
4
13
6
S
R
L
V
V
U
N

Fig. 235.

disc Y. Either 1 or 2 engages one of two projections 7, on a disc 15 fixed upon the sleeve of two cams W, and W, W are loose upon the tappet shaft X. On contact being made between 7 and 1, or 2, the cams make half a revolution, the point of one bears upon a bowl and depresses either lever 8 or 9. Both 8 and 9 are connected by straps 10, 10′ to opposite sides of two pulleys 11, 11′, while 11, 11′ are upon a rocking shaft 12, whose bearings are in the slay swords. 12 has two other pulleys 13, 13′ fixed upon it, and two straps 14 are made fast to these pulleys. The straps 14 are led over guide pulleys in the swivel frame F to opposite ends of the long rack J, which is thereby moved endwise to drive the shuttles A.

Between the fixed disc Y and the boss of the peg wheel P a coiled spring Z is placed. Immediately a Jacquard has released the weighted end of S, the action of Z causes P to slide back along the tappet shaft X until the projection on P is free from the lever 5. The studs 1, 2 are then out of contact with 7, 7 on the cam boss. The lever 5 is at once raised by a spring 20, attached to 5 and to the slay sole. As 5 ascends, the slotted rod 6 lifts the swivel frame F out of action, and the ordinary picking motion becomes operative. At the next sliding movement of the peg wheel P, 5 and 6 again lower the swivel frame. If the stud 1, in making contact with a projection 7, caused lever 8 to be depressed for the first movement, stud 2 will now act through the second projection 7 to cause a cam W to depress lever 9, and so drive the swivel shuttles in the opposite direction. In order to prevent the cams from moving incorrectly, a plate spring M is secured to the frame, and by bearing upon the cam boss, locks it after each half-revolution has been made. When swivelling, the peg wheel P moves the star wheel Q once for each revolu-

tion, and when not swivelling, P moves Q twice for each revolution.

If swivel shuttles move simultaneously with a ground one, two sheds are necessary—the lower one for ground weft, and the upper one for figuring material. But great strain is thereby thrown upon figuring threads, and breakages are numerous. If this scheme could be carried through successfully, the production of a loom would be doubled, see Howarth and Pearson's Jacquard, Fig. 105.

Swivel shuttles may be supported vertically to form a single line, or to form four or five parallel lines. In the latter case four or five colours may be employed in the evolution of one figure. All the shuttles are then suspended from frames, in which a separate groove is cut for each line, and a rack on the top of every shuttle engages pairs of pinions pivoted in a holding frame. In order to conform to the shed lines, and to facilitate refilling, shuttles placed in this manner become shallower as they recede from a reed, and each holder is hinged to the lower edge of a fixed frame, so that any set of shuttles may be instantly turned into a handy position for manipulation.

Circles

Where not more than two colours are required, circles can be successfully employed as substitutes for swivel shuttles, and compared with the older method, a greater number can be placed in a given width. A circle consists of a piece of metal shaped to resemble a horse-shoe; each turns inside two flanged plates, but when in a state of rest the points are towards the warp. Every circle carries on its face a weft spool, and at its rear a series of pins project far enough to gear with the

teeth of a long driving rack. When a frame is lowered, the openings in the shoes permit warp to rise, the rack is moved, and the circles make a complete revolution, in doing which the weft spools enter at one edge of the divided warp and emerge at the other side. On the following figuring pick the rotation is reversed.

So long as the axis of each spool was held at right angles to the warp, it was necessary to leave a transverse space between two figures at least equal to the length of a shuttle. But by placing a spool axis parallel with the warp it is possible to have two spools to an inch. To do this each shuttle holder is made wedge-shaped at the base so that rising warp threads, in sliding along the sides of the wedges, will be pressed far enough apart to make room for the shuttles to drop between them. A swivel rack of this description can either move the shuttles in the opposite direction for the second pick to that they moved in for the first, or in the same direction every time they enter the warp. In the latter event, after rising from the warp each returns to its starting-place, and this gives a closer approximation to embroidery than ordinary swivelling, as well as figures that may cover every part of a fabric.

PART XVI

BEATING UP

Beating up follows picking, and consists in causing a reed to drive each weft thread into its proper position in a fabric. This is best accomplished by a quick forward

stroke, but the slay should recede slowly to afford time for a shuttle to cross the warp.

A slay has been pulled back slowly by the action of cams, and after a shuttle had completed its course, flat springs, placed behind the swords, were suddenly liberated, the energy stored in them being used for beating up. An adjusting screw rendered it possible to obtain a light or a heavy blow. In the pneumatic loom a slay moved in grooves, and two cylinders, with the usual pistons and rods, were employed. At the proper moment compressed air was admitted into both cylinders to drive a slay forward with the requisite velocity, but it was pulled back by weighted straps.

Both these appliances permitted a dwell of any duration, and the intensity of a blow was unaffected by the velocity of other parts of a loom. To this extent they were well adapted for the work to be done, but since such slays could move through various spaces, a constant stroke depended upon the regularity with which a fabric was drawn away. Any variation in this respect would increase or diminish the forward traverse of the slay, and produce thick or thin places in a fabric.

Several positive appliances have been used, such as parabolic wheels, cams, and cranks, but they alter the force of impact between cloth and reed as the speed of a loom changes. In order that the reed might give a sharp stroke upon the cloth, and also leave as much time as possible for a shuttle to move, Dr. Cartwright, in 1788, fixed an elliptical wheel upon the main driving shaft, and geared it with an eccentric wheel upon a crank shaft. When a large side of the elliptical wheel geared with the small side of the eccentric, a superior speed was available for beating up, and when a small side of the elliptical

wheel geared with the large side of the eccentric, a slay moved at an inferior speed, for one was equivalent to a large driving and a small driven wheel, and the other to a small driving and a large driven wheel. Two eccentric wheels have also been employed to produce a like result. Another method of driving a crank shaft differentially is illustrated in Fig. 236, where A is the crank shaft, and F an arm firmly secured upon it. A bowl E is mounted at the extremity of F and rotates between two flanges D,

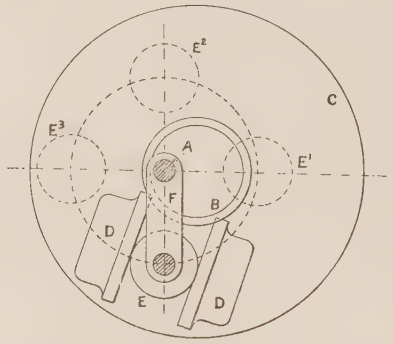


FIG. 236.

which are cast upon a flywheel C. The wheel C turns uniformly upon a hollow boss B; hence, as it rotates, the flanges D carry E, F, and the crank shaft A round in the path indicated by the dotted circles E^1, E^2, E^3. Since E^1 is nearest the centre of C, the shaft A will there move slowest, but at E^3 the bowl is farthest from the centre of C, and the crank shaft will move at its maximum velocity. The position E^1 represents a reed when farthest from a cloth; that of E^3 when in contact with a cloth. A modification of the foregoing was patented in 1870 by A. V. Newton, who bent an extra crank upon one end of

the main driving shaft and passed the end of that crank through a slot in a wheel set eccentric to the cranked shaft. As the slotted wheel revolved the crank was acted upon by different parts of the slot, and turned at a high speed to beat up, and at a low speed when a shuttle was in the warp. For all but wide looms these arrangements are unnecessary.

By one application of cams for governing a slay a grooved cam is fixed upon each extremity of a straight driving shaft. An antifriction roller mounted upon each connecting arm then enters a cam groove. As the cams revolve, the slay is moved to and fro at varying speeds.

In most looms a rocking shaft A, Fig. 237, is supported in bearings bolted to the end framing. Near each extremity of A two arms or swords B are fastened to support a slay sole C. The latter is a piece of sound wood, usually pine, but occasionally ash; it must be strong enough to resist the recurring shocks caused by beating up. A sole C extends across a loom, and upon its upper surface a thin race board is fastened to serve as a shuttle guide. Most race boards are made of birch or beech; they are about half an inch thick, and extend from shuttle box to shuttle box, but iron forms the bottom of the majority of boxes. In 1903 T. Pickles employed lignum-vitæ on account of its hardness and smoothness, and he carried this material through the shuttle boxes. A longitudinal groove E at the back of C is wide enough to receive the lower rib of a reed F. The slay cap G is similarly grooved on its under side to take the upper rib of F, and when G is bolted upon the swords B, the reed is firmly fixed in position. F should, however, be free to make a slight lateral movement, in order that it may adjust itself to the position of the warp. In single shuttle looms a sole equals the length of a slay, but if two

or more shuttles are employed, separate boxes are fitted at one or both ends of C.

Two connecting arms K are fastened by metal straps, gibs, and cotters upon two cranks H which are bent on the

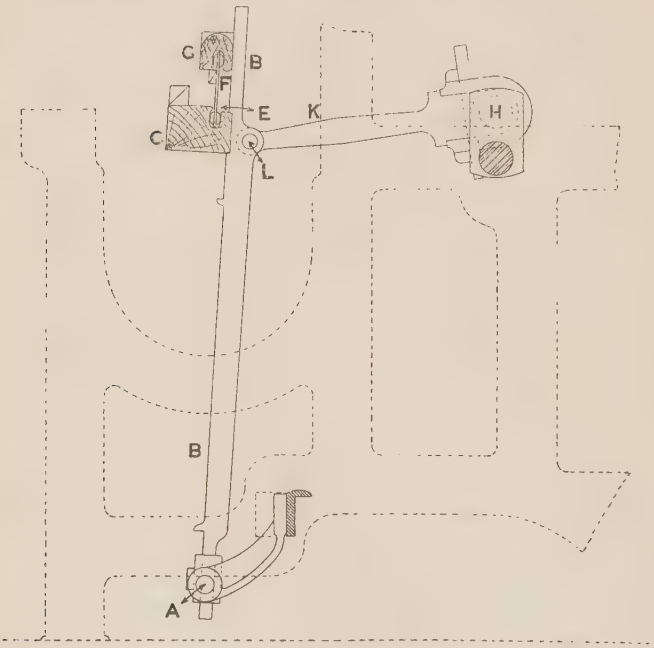


FIG. 237.

main driving shaft, The arms K are fulcrumed to the swords B by pins L. As these cranks revolve, a swinging motion is given to a slay. When the latter is pulled from the fabric a shuttle is driven across; when it is pushed towards the fabric a weft thread is forced into position by the reed. In some looms the connecting arms K are made

in two pieces, as at K, K′, Fig. 238. A supplementary pair of swords B′ are then centred upon the loom framing at A′ and united by pins R to the arms K′. The object of these additions is to hold the forward portions of the arms K′

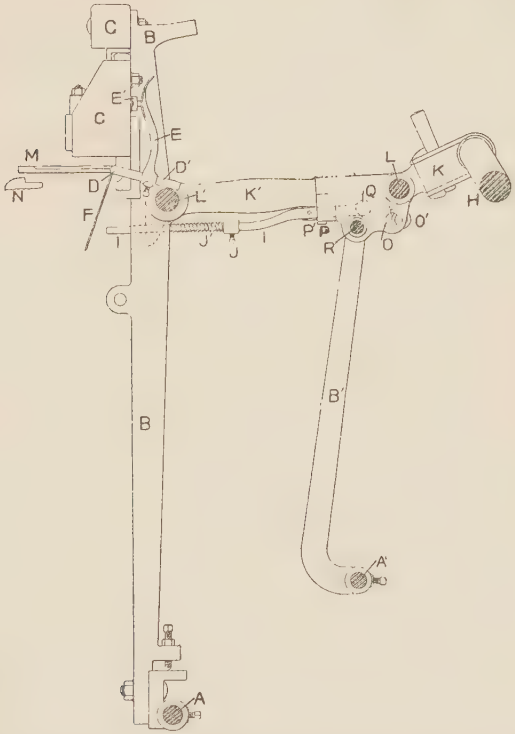


FIG. 238.

almost horizontal as the cranks H revolve. By this means the pins L that connect both halves of the arms K, K′ move in a similar arc to that in which the pins L′ move, and thus upward or downward strain is taken from the slay swords B and the rocking shaft A. The plan also increases the

eccentricity of a slay's movement. Eccentricity may also be regulated by causing the crank pins to work in curved slots formed in two levers united to the slay by the usual arms K.

In order to apply cranks in the best manner, it is important to consider the points where their usefulness may be affected. These points are :—(*a*) The relative positions of the cranks and connecting pins ; (*b*) the diameter of a circle described by the cranks ; and (*c*) the length of the connecting arms. By raising or lowering the connecting pins without altering the crank shaft centre, the eccentric movement of a slay will be modified ; therefore their best relative positions should be defined.

The positions of the crank shaft, the rocking shaft, and the connecting pins may be fixed as follows : Let point A, Fig. 239, represent the centre of a rocking shaft, and the vertical line B a slay sword, for in many looms swords are vertical when a reed and fabric are in contact. C is the centre of a connecting pin which, in narrow looms, may not be more than $1\frac{1}{2}''$ behind the vertical line, but in wide looms it may be carried back to the extent of 14″ by ears cast upon the swords. This permits short connecting arms to be used, and avoids unduly enlarging the cranks. With A, C as radius describe an arc D, to show the path of C when motion is imparted to it. Next find the position of C at the end of its journey by cutting from C, on line D, a point C′ equal to the diameter of the required crank circle. Bisect the line C, C′, and draw a line A, A′ through the pin course at C″, which is midway between the extreme points of oscillation in C. A line E, drawn at right angles to A, A′ and passing through C″, will contain the centre of the crank F. To fix the position of F, with C″ as centre cut from line E the length of the connecting arm, and the parts will give sufficient eccentricity to a

slay, while in c there will be an equal and minimum divergence from a horizontal plane.

If the swords are vertical when a reed touches a cloth,

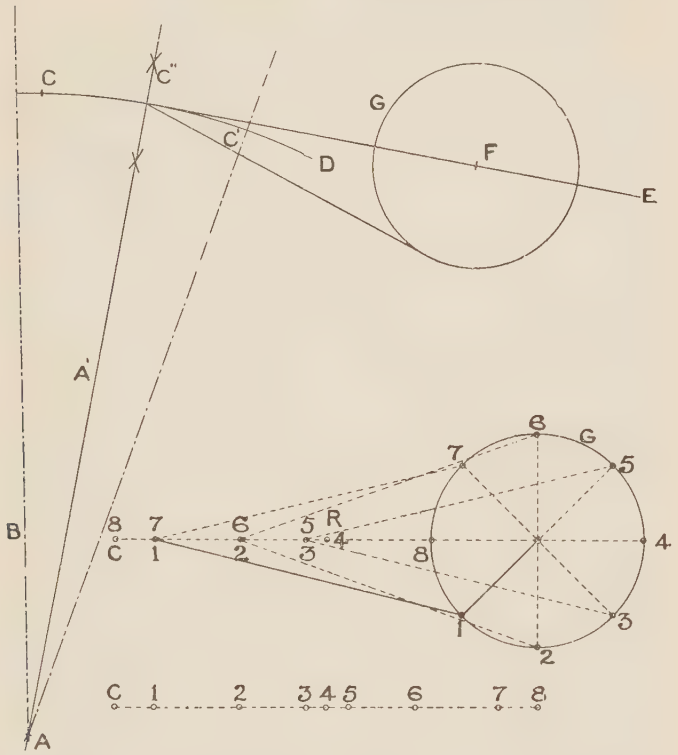


FIG. 239.

and if large cranks are used, the race board in moving backward is liable to be carried too low to permit the bottom line of warp to rest upon it; and unless contact is maintained, shuttles are in danger of flying out. In such cases the swords are often vertical when the cranks are on their

top centres. If the swords are vertical, under the last-named conditions, a slay will pass and repass the centre of the rocking shaft twice for each revolution of the cranks, and this is considered objectionable. A claim is made that a stroke from vertical swords is effective because it is at right angles to a cloth ; but this is not the case, for a cloth slopes from the breast beam to the harness. Hence to push the weft at right angles, the swords must slope backward when the cranks are on their front centres. But whether the swords are vertical, inclined forward or backward, the method for finding the relative positions of the rocking shaft, the connecting pin, and the crank centres applies, provided the first line erected represents the most forward position of the reed. The race board must be parallel with the bottom shed when a shuttle is moving across.

Valuable eccentricity in a slay is represented by the difference in the velocity of a connecting pin, as a crank passes through a given number of degrees above the front centre, and an equal number of degrees below the back centre. If the rotary motion of a crank is converted into reciprocating rectilinear motion, equal angular spaces in a crank circle will give unequal rectilinear movement to a connecting pin. With a long arm the difference is slight, but with a short one it is considerable. In the lower detached diagram, Fig, 239, a crank circle G is divided into eight equal angular spaces. C 8 is the length of a connecting arm, and C a point to be moved in a horizontal plane. If the crank is moved :—

To the end of division	1,	the point C will have travelled from	C	to	1	
At the end	„	2	„	„	1	„ 2
„	„	3	„	„	2	„ 3
„	„	4	„	„	3	„ 4

and in like manner back again to 8.

All the spaces C to 4 are unequal, 1, 2 being the largest and 3, 4 the smallest, but the difference between the spaces 7, 8 and 3, 4 is of most importance, as 7, 8 represents the speed of a slay for beating up, and 3, 4 its speed while a shuttle is in the warp.

Cranks and connecting arms cause a slay to move irregularly, because the arms are pulled in a more or less diagonal direction; this places the forward ends of the arms at varying distances from the crank centres, while their rear ends are held at a fixed distance from those centres. Therefore if the cranks move through 90 degrees from the front to the bottom centres, they will pull a slay through a space equal to the radius of a crank circle, plus the difference in length between a straight and a tilted connecting arm when measured on a horizontal line. Further, as the cranks pass from the bottom to the back centres, the movement of a slay, when measured as stated above, equals the radius of the crank circle, minus the increased length of the arm due to changing it from a tilted to a horizontal position.

The precise amount of variation can be readily found by means of a diagram. In Fig. 240 A is the circle described by a crank, and B, C the length of a connecting arm. When the crank has passed from C to C′, the arm is tilted as at B′ C′, and therefore shortened if measured on the line A, B. To find how much it is reduced in length take B, C as radius, and from point B′ describe an arc C′, 3; the space 2, 3 represents the loss in length, and C, 3 the actual movement of the connecting pin. The crank has caused the pin to be moved through a space equal to C, 2; and tilting the arm B, C′ has moved it through an additional space 2, 3.

Calculations can be made to ascertain the variation; thus, if the crank circle has a radius of $2\frac{1}{2}''$, and the con-

necting arm is 10″ long, the actual movement of the pin B, while the cranks are moving from the top to the front centres, and from the bottom to the back centres, can be found by assuming that two sides of a right-angled triangle are given to find the length of the third. For the radius of the crank circle equals the altitude, the length of the arm equals the hypothenuse, and the base is required. The length of the base is found by squaring both sides, subtracting one square from the other, and extracting the square

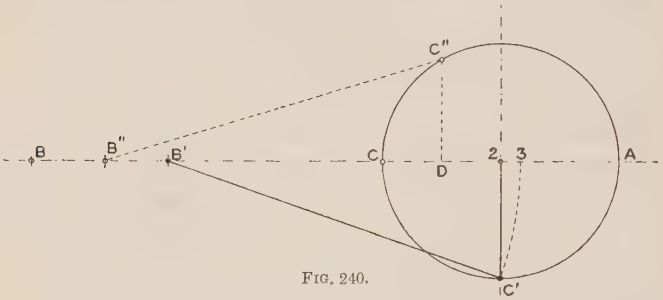


FIG. 240.

root from the remainder. Thus : $\sqrt{10^2 - 2{\cdot}5^2} = 9{\cdot}68'' =$ the length of a tilted arm, or a loss of $10 - 9{\cdot}68 = 0{\cdot}32''$; hence the actual movement of a connecting pin for each quarter of a crank's revolution is :—

Top centre to front .	2·5″	the radius of circle	+ 0·32 = 2·82″
Front centre to bottom	2·5″	„	+ 0·32 = 2·82″
Bottom centre to back	2·5″	„	− 0·32 = 2·18″
Back centre to top .	2·5″	„	− 0·32 = 2·18″
			10·00″ =

the complete movement of a connecting pin for one revolution of a crank. In these calculations the fact that a connecting pin moves in the arc of a circle has been neglected, because the difference is so small that it is unimportant.

It is more difficult to determine the travel of a connecting pin for other than 90 degrees of angular movement, for the altitude of the triangle formed is not known. But by the aid of the accompanying table of natural sines and versed sines the movement may be obtained : -

Table showing the Motion of a Crank

(Crank = 1 inch)

Degree.	Sine.	Versed Sine.	Degree.	Sine.	Versed Sine.	Degree.	Sine.	Versed Sine.
1	·0174	·0001	31	·5150	·1428	61	·8746	·5152
2	·0349	·0006	32	·5299	·1519	62	·8829	·5305
3	·0523	·0013	33	·5446	·1613	63	·8910	·5460
4	·0697	·0024	34	·5592	·1709	64	·8987	·5616
5	·0871	·0038	35	·5735	·1808	65	·9063	·5773
6	·1045	·0054	36	·5877	·1909	66	·9135	·5932
7	·1218	·0074	37	·6018	·2013	67	·9205	·6092
8	·1391	·0097	38	·6156	·2119	68	·9271	·6254
9	·1564	·0123	39	·6293	·2228	69	·9335	·6416
10	·1736	·0152	40	·6427	·2339	70	·9397	·6579
11	·1908	·0183	41	·6560	·2453	71	·9455	·6744
12	·2079	·0218	42	·6691	·2568	72	·9510	·6909
13	·2249	·0256	43	·6819	·2686	73	·9563	·7076
14	·2419	·0297	44	·6946	·2806	74	·9612	·7243
15	·2588	·0340	45	·7071	·2929	75	·9659	·7411
16	·2756	·0387	46	·7193	·3053	76	·9702	·7580
17	·2923	·0437	47	·7313	·3180	77	·9743	·7750
18	·3090	·0489	48	·7431	·3308	78	·9781	·7920
19	·3255	·0544	49	·7547	·3439	79	·9816	·8092
20	·3420	·0603	50	·7660	·3572	80	·9848	·8263
21	·3583	·0664	51	·7771	·3706	81	·9876	·8435
22	·3746	·0728	52	·7880	·3843	82	·9902	·8608
23	·3907	·0795	53	·7986	·3981	83	·9925	·8781
24	·4067	·0864	54	.8090	·4122	84	·9945	·8954
25	·4226	·0937	55	·8191	·4264	85	·9961	·9128
26	·4383	·1012	56	·8290	·4408	86	·9975	·9302
27	·4539	·1089	57	·8386	·4553	87	·9986	·9476
28	·4694	·1170	58	·8480	·4700	88	·9994	·9651
29	·4848	·1253	59	·8571	·4849	89	·9998	·9825
30	·5000	·1339	60	·8660	·5000	90	1·0000	1·0000

The sine of any angle is in proportion to the length of a line dropped from a point in the periphery of a circle, at right angles to, and upon the diameter line (see C″, D, Fig. 240). The versed sine is the distance between the sine and the periphery of a circle when measured on the diameter line, as C, D. For example, let A, B be the diameter line, C″ a point 60 degrees from C, then the sine of 60 degrees is in proportion to C″ C, which is also the altitude of a triangle B″, D, C″ B″; and D, C is the versed sine which shows the movement of a pin due to a crank. If the circle has a radius of 4 inches, and the arm is 12 inches long, the sine of 60 degrees being 0·8660, and the versed sine 0·5 for a circle 1 inch in radius, then for a circle 4 inches in radius, $0{\cdot}866 \times 4 = 3{\cdot}464$ inches, and $0{\cdot}5 \times 4 = 2$ inches $\therefore \sqrt{12^2 - 3{\cdot}46^2} = 11{\cdot}5$ inches, the length of the base, and also of the inclined arm, or a loss of $12 - 11{\cdot}5 = 0{\cdot}5$ inch, and $2 + 0{\cdot}5 = 2{\cdot}5$ inches, the motion of a connecting pin. To find the eccentricity of a slay take a given number of degrees above the front and below the back centres. Ascertain the movement at each place, and subtract one from the other. The more a connecting arm is tilted the greater the eccentricity; hence, increasing the throw of a crank, shortening a connecting arm, or both, will increase eccentricity. Also, by reducing the throw of a crank and lengthening a connecting arm, opposite results will follow.

Eccentricity may be definitely increased or diminished. For example, a $2\frac{1}{2}$″ crank in turning through an angle of 180 degrees from the front centre will, during the first 90 degrees of movement, pull the connecting pin of a 10″ arm $2{\cdot}5 + 0{\cdot}32 = 2{\cdot}82$″, and for the second 90 degrees will move it $2{\cdot}5 - 0{\cdot}32 = 2{\cdot}18$″, hence $2{\cdot}82 - 2{\cdot}18 = 0{\cdot}64$″ the eccentricity (see p. 460). What size of crank must be used with a 10″ arm to give 0·8″ eccentricity?

$$0{\cdot}64 : 0{\cdot}8 : : 2{\cdot}5^2 : 7{\cdot}8125$$
$$\sqrt{7{\cdot}8125} = 2{\cdot}795'' \text{ the crank required.}$$

For Proof.

$$\sqrt{10^2 - 2{\cdot}795^2} = 9{\cdot}6014$$
$$10 - 9{\cdot}6014 = 0{\cdot}3986'' \text{ due to tilting the arm.}$$
$$2{\cdot}795 + 0{\cdot}3986 = 3{\cdot}1936$$
$$2{\cdot}795 - 0{\cdot}3986 = 2{\cdot}3964$$
$$0{\cdot}7972 = \text{eccentricity.}$$

To determine the length of stroke to be given to a slay, the breadth of loom and the make of fabric must be taken into account, the former because the number of revolutions made by the cranks in a given time must be reduced as breadth is increased. There is a speed above and below which a loom does not increase its productiveness, but manufacturers seldom follow any definite rule in fixing the relative velocities of wide and narrow looms that produce similar fabrics. The most efficient speed may be determined by comparing the lengths of weft consumed in a given time by looms weaving wide and narrow pieces of similar quality. If the loom using the greatest length of weft is taken as a model, the plan for speeding one of any other breadth is to cause the shuttles in both to move at the same velocity.

The space through which a reed moves is greater than the throw of a crank, in proportion to the height of the connecting pins and the beating-up point of a reed. Thus, if the centre of a rocking shaft is 28″ from the centre of a connecting pin, 31″ from a fabric, and a crank describes a circle of 5″, the movement is as 28 : 31 : : 5 : 5·33″.

In carpet and certain other heavy looms it has been found necessary to give weft two blows in quick succession,

and the plan adopted is to straighten two arms which are knuckle-jointed twice during each revolution of a crank. Each time these arms are straight the weft receives a blow. In Fig. 241, A is a sword, B a crank, C a connecting arm, D the knuckle joint, E is an arm hinged to the framing, and F another arm attached to a slay by the usual connecting pin, and to E by the pin D. In one drawing the

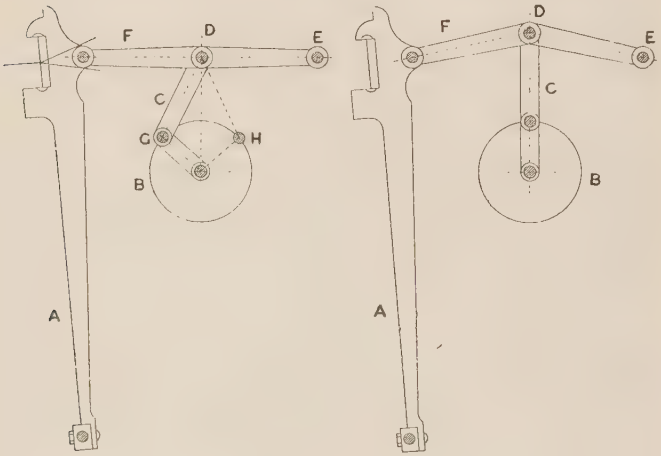


FIG. 241.

arms E, F are straight, but when the crank B moves from point G to the top centre, D is pushed up, and E, F are bent. When B reaches point H on the opposite side, the arms are again straight. The time that elapses between the first and second straightening can be increased either by moving the crank centre up or by lengthening the arms G. It can be reduced by lowering the crank or shortening C.

PART XVII

THE REED

A REED is used to beat up weft inserted by a shuttle; it also helps to keep warp threads in their proper positions; it forms a back guide for a shuttle to run against; and it determines the fineness of a fabric.

Prior to 1733 reeds were made of cane or split reed, but in the above-named year John Kay substituted flattened brass or iron wire, and the change was welcomed as an important improvement. Reeds are now made from iron and brass wire, which is flattened by rollers, and its edges are straightened by leading it in a serpentine course, amongst a series of pegs; the ribbon is then cut to a uniform width equal to that of the dent required. The edges are next rounded and smoothed by files placed to act on every part of the wire as it passes along. After being straightened on the flat, the wire is forwarded to the reed-maker, who feeds it into a machine that automatically cuts it into equal lengths, inserts each strip in position, winds tarred bands between the strips and round two pairs of ribs, and compresses all to the required gauge, at the rate of from 300 to 400 dents per minute.

A finished reed consists of a series of parallel flat wires D, see A, Fig. 242, which are secured at their extremities by passing tarred cotton cords C between the dents and round two semicircular wooden rods B. The cord usually consists of strands of fourfold 32^s twist, varied to suit the

space between dent and dent. But round iron wire is occasionally used in place of wooden ribs and cotton cord, in which event the whole is fastened by solder.

In 1896 T. Pickles, and J. W. Smith, secured one end of every dent between two rods B by tarred cord in the usual manner, but bound them lightly together at the other end with spirally wound wire, or untarred thread, their object being to permit the dents to yield more readily to the passage of knots or other obstructions. Reeds are sometimes made double by placing two sets of wires between laths, so that those of one set face the spaces of the other. Such reeds prevent loose fibres of unsized warps from matting together and choking the sheds.

Reeds are also constructed to produce definite effects in fabrics. In reed E, for example, groups of dents D are set obliquely in the ribs B, and each dent is much longer than usual. When in use this reed is slowly raised and lowered by the action of a cam, and its oblique dents draw some groups of warp threads closer together, but permit others to open out; thus destroying the parallel arrangement of a warp by throwing the threads into wavy lines. At F all the dents D converge towards the top rib B. If such a reed be raised and lowered by a cam, the fabric produced will vary in breadth; when the beating-up point is near the bottom rib a piece will be broadest, and when near the top rib a piece will be narrowest. This reed is used in the manufacture of slipper uppers, and for other purposes.

At G and H two reeds are shown in plan and elevation. Both have soft-metal ribs B, and in both the dents D are parallel, but the plans show one dent set in advance of another. At G they form a curved line, at H a zigzag line. With such reeds weft will not be beaten up at right

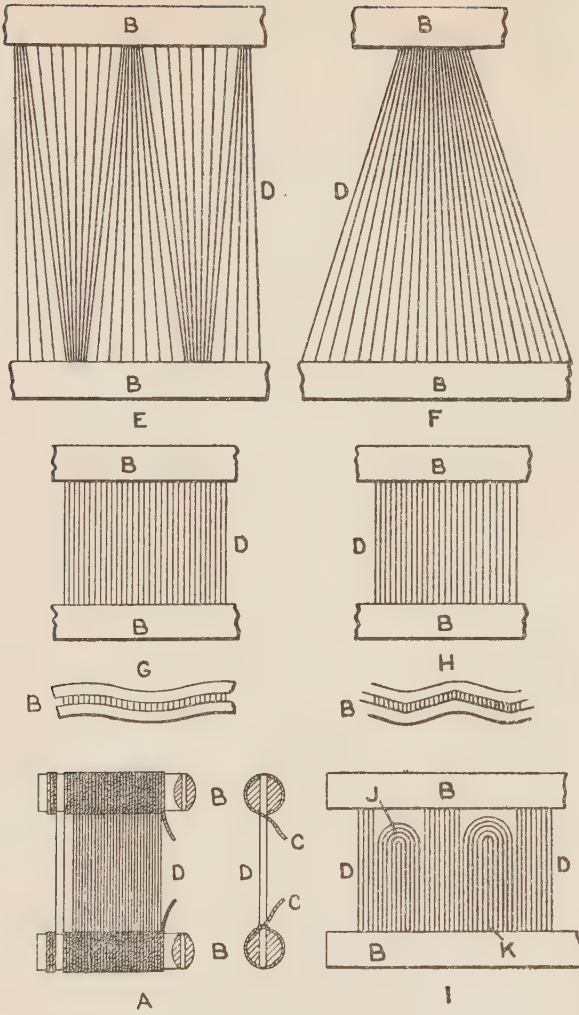


Fig. 242.

angles to warp, but will correspond with the facial conformation of a reed. At I two kinds of dents, D and J, are used. Those at D are of the type illustrated at A. But the dents of J are either formed by bending a wire and fastening both ends in the lower rib B : or two straight pieces of wire have brass curves brazed upon their upper ends. Such a reed is used for gauze weaving. All threads are free to cross in their respective dents, and in addition the threads drawn into the curved dents are capable of crossing threads contained in intervening dents. The scheme of construction admits of almost indefinite variation. Any number of straight dents may be soldered upon the inside of a curved dent, as at K, but, unlike the gauze reed, Fig. 141, these are also used to beat up weft.

For cotton fabrics reeds have from 6 to upwards of 120 dents to the inch. A reed-maker calls each flattened wire a "dent," namely a tooth, but manufacturers generally call each space between two wires a dent. A reed contains a definite number of dents on a given length ; this is termed the count, the pitch, or the number of the reed. The counting of reeds has, however, been unnecessarily complicated by varying the basis of nomenclature.

The following classified list of reeds in use will probably place the matter in its simplest form :—

Certain reeds are named from the number of dents contained on one inch, as—the Radcliffe, the Huddersfield, and the American.

Other reeds are named from the number of dents contained on a certain number of inches ; of these the most important are—the Stockport, which is on 2″, the Scotch on 37″, and the Macclesfield on 36″.

Reeds are also named from the number of groups of 20 dents on a certain number of inches, each group being

called a beer, or porter, as in—the Bolton reed, which is based on $24\frac{1}{4}''$; the Bradford on 36″; the Dundee on 37″; and the Worsted on 54″.

The Dewsbury reed has 19 dents to a group, or beer, on 90″; the Holmfirth reed has 5 dents to a group, or beer, on 12″.

In some silk reeds, the pitch, the warp threads per dent, and the width go together, as a 2000 reed, 8 thread, 24″; or an 1800 reed, 4 thread, 18″.

Of the foregoing the Stockport reed is in most extensive use, and bids fair to supersede others in Lancashire.

The most useful comparison is the number of dents per inch in a number 1 reed of each system. To find which use the following rule:

$$\frac{\text{Count} \times \text{dents per beer}}{\text{Inches in the basis}}.$$

Thus Stockport, $\frac{1}{2} = 0{\cdot}5$ of a dent per inch.

Bolton, $\frac{1 \times 20}{24{\cdot}25''} = 0{\cdot}8247$ of a dent per inch.

Radcliffe	No. 1 reed	= 1	dent per inch.
Huddersfield	,,	= 1	,, ,,
American	,,	= 1	,, ,,
Stockport	,,	= 0·5	,, ,,
Scotch	,,	= 0·02702	,, ,,
Macclesfield	,,	= 0·02778	,, ,,
Bolton	,,	= 0·8247	,, ,,
Bradford	,,	= 0 5556	,, ,,
Dundee	,,	= 0·5405	,, ,,
Worsted	,,	= 0·3704	,, ,,
Dewsbury	,,	= 0·2112	,, ,,
Holmfirth	,,	= 0·4167	,, ,,

The count of one reed may be converted to its equivalent count in another reed, as follows:—

$$\frac{\text{Given count} \times \text{dents per beer} \times \text{inches in the basis of the required count.}}{\text{Inches in the basis of given count} \times \text{dents per beer of the required count}}.$$

Example.—What does a 40 reed Bolton count equal in the Dundee and Stockport systems?

$$\frac{40 \times 20 \times 37''}{24{\cdot}25'' \times 20} = \text{a } 61{\cdot}03 \text{ Dundee reed, and}$$

$$\frac{40 \times 20 \times 2''}{24{\cdot}25''} = \text{a } 66 \text{ Stockport reed.}$$

PART XVIII

TERRY MOTIONS

THE so-called "Terry" or Turkish towelling textures form a branch of the pile industry, and require special mechanism for their production. The features that distinguish these fabrics from others are: That two warps are needed, one for ground, the other for pile; and that weft is only partially beaten up at the time of insertion. A ground warp is, during weaving, held as tense as the strength of the material will admit of, but a pile warp can be readily drawn from its beam. Both warps may be controlled by heald harnesses, or the ground warp may be controlled by healds, and the pile by a Jacquard. In either event both are interlaced with the weft threads. Three, four, or five picks are inserted to each transverse line of loops, but two of them are not at once driven into the positions they are intended to occupy in a fabric,

then similar groups are similarly treated. Between the last pick of the first group and the first of the second one, a gap is left, whose width is varied to suit the length of pile to be manufactured. In beating home a group of three picks this gap must be closed, by making the weft slide along the tense ground warp, and so draw the pile warp forward with the weft, thus forming loops upon the upper or the lower surface. By using a suitable shedding harness each warp thread may be looped above or below at pleasure, but all must loop either in one direction or the other. Hence a Turkish towelling fabric differs from true terry, because in the latter the same number of loops need not be formed in every line.

Two systems have been introduced for forming gaps: one requires a fast reed and a variable swing in the slay; the other a loose reed and a uniform swing in the slay. Mechanisms of the most varied description have been devised for both systems. One inventor mounts a crank shaft in movable bearings, and, by means of levers and links, unites the bearings with a latched cam. By lifting or dropping the latches a bowl will be moved from one cam groove to another. When in one groove, the crank shaft is pushed forward to beat up; when in the other groove, the shaft bearings are drawn back and the reed is no longer able to reach the cloth fell. The number of revolutions made by a crank shaft when in each position is determined by the shedding motion. Another plan consists in mounting a driving shaft in the vertical arms of two cranked levers, the horizontal arms of which are adjustably weighted and rest upon cam surfaces. As the cams rotate, the cranked levers push forward and draw back a crank shaft, to beat up and to leave a gap respectively.

Crank shaft bearings have been fixed and a variable traverse given to the slay by other means. Thus both connecting pins on the swords have supported pendent levers that terminated in curved slots, and the connecting arms were attached to the pendents. Two levers mounted upon studs in the frame each held a bowl in a slotted pendent. These bowls formed the fulcra upon which the pendents swung. By raising or lowering the bowls leverage was altered, and consequently the traverse of a slay varied. A cam decided when, and how far, the bowls should move in the slots. Eccentric pins have been used to unite the swords and connecting arms; the eccentrics were turned half a revolution, by wheel-gearing, for each change in the throw of a slay. When the full sides of the eccentrics faced the reed a slay moved its minimum distance, but when their full sides faced the cranks a group of picks was beaten home. A reed may be fast and a slay swing uniformly, if the breast beam and back rest of a loom are connected and made to slide to and fro. In moving forward they carry the cloth fell beyond the reed stroke; in moving backward the cloth fell is placed in its normal position, and a group of picks beaten up.

Swivelling, or loose reed terry motions are numerous, and more extensively used than fast reeds. One of the oldest of these contrivances consists in placing the lower rib of a reed in a case, to each end of which a latch is attached. Beneath the latches a bar receives a vertical reciprocating motion from a cam. In rising, this bar lifts the latches against the slay sole to lock a reed; in falling, the latches face fixed pins and, as the slay advances, contact is made between them, and both case and reed are thrust back to form a gap. Two recent devices will indicate the nature of loose reed terry motions.

Hacking's Terry Motion

This piece of mechanism permits a slay to move uniformly, but imparts to a reed a variable traverse. It consists in allowing a reed A, Fig. 243, to swing freely in the slay cap B, but the base of A is placed in a case C, which extends across the warp space. Two arms D unite C with a shaft E whose bearings are on the swords. C may be pressed against a slay back and moved out of contact

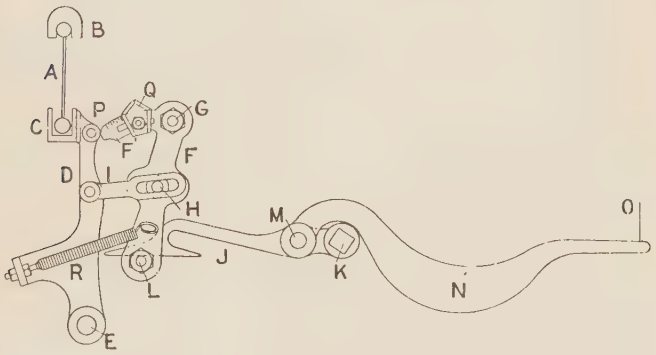


Fig. 243.

with it at pleasure. Thus: A lever F is fulcrumed at G upon one ear of a sword; its upper curved arm F′ is graduated to facilitate the adjustment of a stop Q, that regulates the length of pile. F is moved about its centre G by hinging a hook J upon a stud K in the loom frame, so that J may engage with, or be detached from, a stud L in the lever F. An arm N is free to move upon a pin M in J, and is sufficiently heavy normally to hold J above L. From the rear of N a wire O is led to

a jack in a dobby, or a hook in a Jacquard. By lifting N the hook J falls, and as a slay advances with D, F, to beat up, L is arrested, this depresses F′, and permits a bowl P, mounted upon a pin in D, to roll along the upper face of F′ until a stop Q is reached. As P traverses F′, a coiled spring R draws D, C, and A away from a slay sole; the distance they move being regulated by the position Q occupies on F′. An adjustable stud H is fixed in F, to receive a slotted link I which is centred upon D. When the bowl P impinges upon Q, the stud H is at the end of the slot in I, and prevents a reed from jumping forward. By allowing N to fall, J disengages itself from L, the spring R draws the concave nose of F′ to face the centre of P, in which position L impinges upon the sword, and a reed case is securely locked.

In this loom a dobby automatically effects every change required to weave Turkish towels, namely: It causes the warps to be drawn forward to form fringes. It inserts more picks per inch in the headings than in the body of a towel. It places, where required, differently coloured wefts in a fabric, and forms terry. It changes from one weave to another, measures the length of each, slackens the pile warp for weaving terry, and tightens it for the headings.

Hattersley's Terry Motion

Messrs. Hattersley also make a terry motion for a swivelling reed. It is constructed and operated as follows: A, Fig. 244, is a reed whose upper rib is held in a slay cap, C is a reed case, D one of several supporting arms for C, and E a shaft mounted upon the swords,—all of which are similar in construction and action to those in the pre-

ceding figure. Upon E a collar, provided with a projecting lip M, is fixed; a lever, F, G, is also loosely mounted upon E. Two lugs K, on the under side of F, G, have

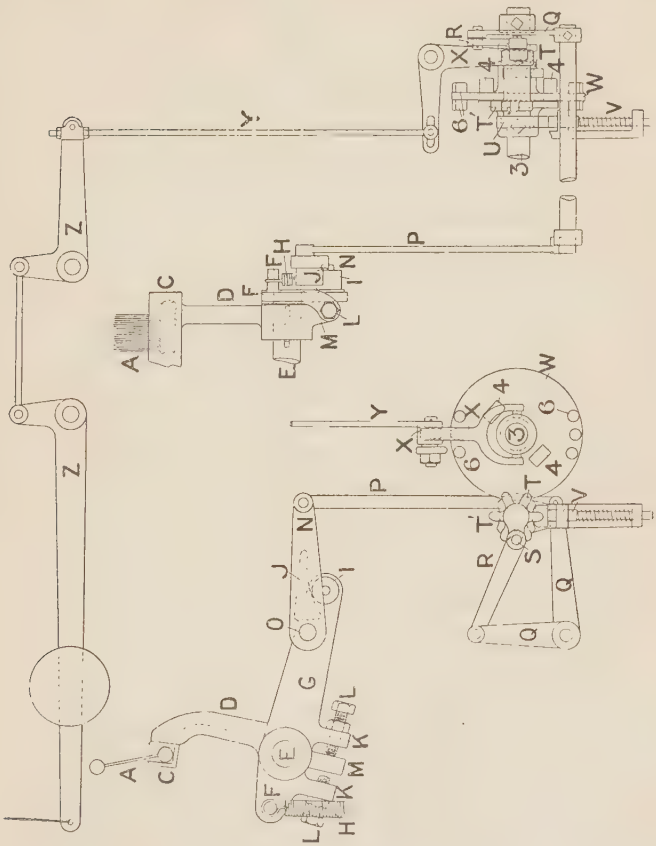


FIG. 244.

adjusting screws L fitted in them for the purpose of regulating the length of pile. A spring H on arm F draws the front screw L against M and holds a reed in position

for beating up. The rear screw L is thus normally out of contact with M; it determines how far a downward movement in G shall draw back a reed A. Arm G terminates in a bowl I, and, as a slay moves to and fro, I rolls upon the upper or the lower slope of a wedge J, formed on one face of a lever N, whose fulcrum is at O. A link P unites N with a cranked lever Q, and a rod R connects Q with a crank S which is loose upon a stud. The boss of S is compounded with a double-notched locking plate U for a hammer V to act upon; also with two sets of teeth T, T′. Each set consists of three teeth that cover half the circumference of the boss. Those forming one set are on the opposite half of the boss to those of the other set, but are not in one line, yet, taken together, they equal a wheel of six teeth. Crank S is moved by mounting a sliding peg disc W upon the picking shaft 3, and rotating it by two prongs 4 of a forked boss fixed upon 3. Disc W has on each face two sets of three pegs 6; the outer sets engage the teeth T intermittently, and move the crank S from its front to its back centre. In doing this the wedge lever N is lowered and the bowl I mounts the upper surface of J to lock a reed. But when the inner sets of peg 6 engage the teeth T′, the crank S moves from its back to its front centre, lifts the wedge lever N until bowl I rolls along the under surface of J, and withdraws a reed from a slay sole. In the boss of W a ring groove receives the prongs of a forked cranked lever X, whose other arm is attached to a rod Y for the purpose of coupling it with a cranked lever Z. From the upper arm of Z a rod passes to a second cranked lever Z, which is flexibly connected with the shedding harness, and sufficiently weighted normally to thrust the forks X and the pegged disc W inward upon the picking shaft. But when Z, Z are moved, the outer pegs

in W engage the teeth T; when Z, z are undisturbed, the inner pegs in W engage with teeth T′ until a smooth part of the boss of S faces the pegs, when the latter are free to rotate without disturbing S.

Terry fabrics are known as three, four, five, and six picked; these terms refer to the schemes of weaving. In a three-picked weave a reed is loose for two beats of the slay and locked for the third, hence three picks form a group which must be beaten home simultaneously. In four and five picked weaves a reed is loose for two beats, and locked for the remaining beats to form groups of four and five picks respectively. But a six-picked terry has its weft beaten up in groups of three picks, with a different scheme of interlacing warps with weft for the second group from that adopted for the first one.

It is customary to put terry pile warps under tension as for ordinary goods, but it is difficult to form pile of uniform length. On the latter account many patents have been procured for automatic mechanisms that deliver fixed lengths of warp each time a reed is locked. By most of these devices a pile beam is either placed upon an intermittently driven drum, and the warp is unrolled by frictional contact; or the warp is nipped between intermittently driven rollers. But cost of upkeep, or lack of efficiency, has prevented their general adoption.

During recent years looms have been introduced which have made it possible for one weaver to attend four looms where formerly two were the maximum number. This has been accomplished by controlling the various changes from a dobby. Thus in the case of the making of an ordinary terry towel with coloured headings and fringes the following changes have to be made. The body of the towel being taken as normal, when the terry-making

device is at work and the terry warp is slack; when this is completed the terry motion must be put out of action, an increase in the number of picks must be made, and "plain," *i.e.* terry weave with both warps tight must be produced for a specified length; then extra white and coloured wefts of a coarse count must be introduced for cord headings. During this period the weave is changed, picks being put in with the first, fifth, and first ends raised on three succeeding picks, followed by picks with the first, fifth, and first ends left down on three succeeding picks. This produces a very thick cord heading, and is continued as long as may be required; this may be followed by another portion of "plain," after which the fringe is drawn down mechanically. All these operations and changes are automatically controlled, thus taking from the weaver what was previously the main portion of her work. The looms have proved highly satisfactory.

In the weaving of large Jacquard terry patterns, many attempts have been made to simplify the designing and reduce the number of cards. In some cases two hooks have been controlled by one needle, and one card has been presented to the needles for three or more picks, instead of one needle for each hook and one card for each pick, thus effecting a considerable saving in both designing and cards.

Some years ago W. Myers invented a machine in which four hooks were controlled by one needle, and one card was used for three or more picks according to the loop to be made, thus reducing the number of cards from six to one for a three-pick terry.

The essential parts of the machine are shown at Fig. 245. Each card is presented to the needles for three or more picks, during which time the griffes are worked to produce the weaves shown at L, M or N, O.

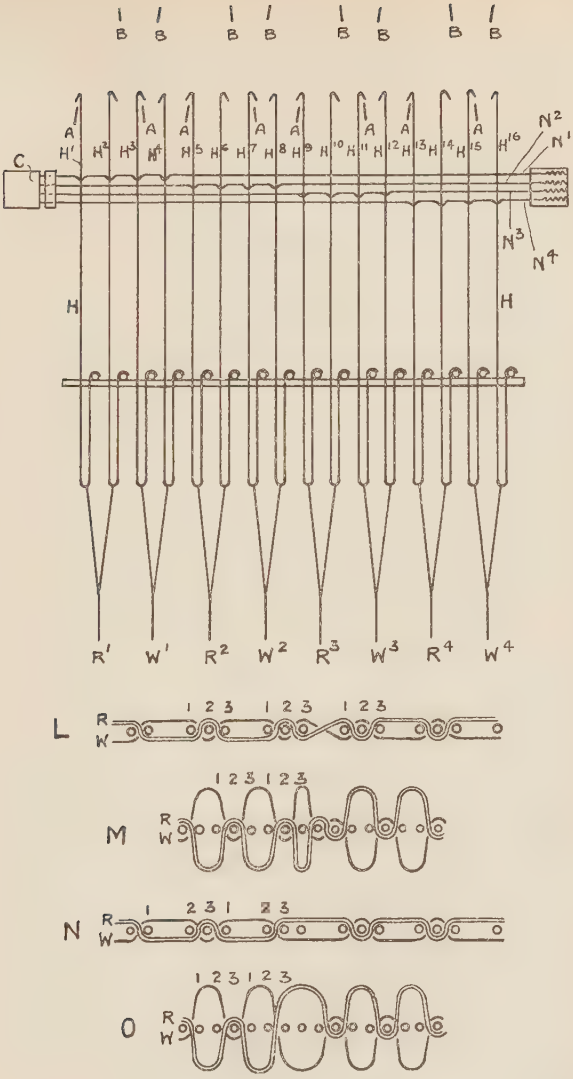

B B B B B B B B
A H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
C
N2 N1 N3 N4
H H
R1 W1 R2 W2 R3 W3 R4 W4
L R W 1 2 3 1 2 3 1 2 3
M R W 1 2 3 1 2 3
N R W 1 2 3 1 2 3
O R W 1 2 3 1 2 3

FIG. 245.

The machine is designed to weave figure and ground in solid terry, such as is commonly met with in lettered towels and figured bath mats.

For a three-pick terry griffe A is raised on picks 1 and 3, and griffe B is raised on pick 2. Therefore if it is desired to weave a red figure on a white ground, the design will be painted up in red and the ground left blank for the white portion.

Holes in the card will allow hooks H^1, H^5, etc., to be lifted on picks 1 and 3, thus making red figure, whilst blanks in the card will allow hooks H^3, H^7, etc., to be lifted to form white ground. To make terry in the opposite colours at the back of the cloth, the blanks in the card will cause hooks H^2, H^6, etc., to lift red ends on pick 2, to bind the red ends under the white ground, and holes on the card will cause hooks H^4, H^8, etc., to lift white ends on pick 2 to bind the white under the red figure.

Specially designed cams are used to operate the griffes in the desired manner, and to control the cylinder.

The most desirable weave is shown at L and M, but this requires that the griffe A shall be up on pick 3, then sink and be up again on pick 1. This practically converts the machine into a single lift so far as speed is concerned. For ordinary goods, such as towels, this is a distinct disadvantage, and has prevented the development of the machine. For wider goods, where the speed of the loom is much slower, the machine could be used to advantage. Another plan of weaving is shown at N, O, but here it will be observed that a long loop is made at the change, and this is considered objectionable, as all these long loops appear at the edge of the figure; therefore, although a higher speed may be obtained, it is at the expense of the appearance of the figure.

PART XIX

WARP AND WEFT STOP MOTIONS

Warp Stop Motions

In the year 1786 Dr. Cartwright patented a device for stopping a loom on the failure of a warp thread, and numerous inventors have since endeavoured to improve upon his scheme. Most of these inventions, however, were ignored until the problem of automatically supplying a loom with weft was forced into notice. It then became apparent that the number of looms which could be allotted to one weaver was limited by the attention to be given to warp breakages, and that only a warp stop would enable a radical change to be effected.

The following distinct types of warp stop motions are in use :—(*a*) Dr. Cartwright's plan, where detectors are independent of the shedding mechanism and severally suspended from the warp threads. In these, so soon as a fracture occurs, one detector falls into contact with a vibrating bar connected with the starting gear, and the loom is brought to a stand. (*b*) Those in which metal healds form detectors: —Here, at one point in the movement of a shaft, each heald is supported by a warp thread until a fracture occurs, when a heald falls by gravitation into the path of a vibrator, and the loom stops. The Boyne and one of the Northrop stop motions are of this type. In all motions included in groups *a*, *b*, connection between the detectors and the starting gear may be made either mechanically or electrically.

(*c*) Those in which steel wires are passed between pairs of crossed warp threads and, during weaving, are bent towards the shedding harness, but on the failure of a thread a liberated wire moves back into contact with a metal plate and electro-mechanical connections stop the loom.

Efficiency depends to some extent upon the positions detectors occupy in a loom. If they are on the shedding harness, the necessity for twice drawing in a warp, for dropping detectors over warp threads, or for threading wires amongst a warp is obviated. Further, since threads break most frequently in or before the healds, when detectors are placed between the lease rods, or in the positions usually occupied by lease rods, there is a risk of broken threads wrapping round unbroken ones and preventing those detectors from acting quickly. An efficient stop motion must have a wide range of application; it must be readily adaptable to different types and different widths of looms, to different materials, to varied counts of yarns, and to fabrics requiring two or more warp beams. Such a device improves the quality of cloth by causing weaving to cease when threads are broken; it reduces the number of floats, and prevents broken threads from breaking others. But heavy detectors are liable to break threads which would otherwise remain intact. The accompanying figures show different types of detectors and different methods of operating them.

The Northrop Warp Stop Motion

The Northrop warp stop motion consists in suspending a drop detector from each warp thread, so that its basal end shall be above a vibrating comb, until, through the

breaking or slackening of a thread, a detector descends into the path of the comb; when the driving handle is moved to stop a loom. Each drop A, Fig. 246, is made from a thin strip of smooth metal, approximately 5″ long by $\frac{7}{16}$″ broad. The upper portion is slotted, and at one place its breadth is reduced to facilitate the locating of a broken thread. Beneath the slot an eye is punched for a thread, but below that the metal is solid. The slots in A enable them to be threaded upon two bars B, which are placed about $1\frac{1}{4}$″ apart. These bars are held in the ends of a frame C, consisting of two sides and two ends. Upon the lower edge of each side piece a strip of finely serrated metal is screwed with its serrations inside. The end pieces of C are attached to the framework, and provide bearings for a shaft D. This shaft is furnished with a series of arms for the support of a thin plate E, finely serrated along both edges. All the above-named parts are fixed from 6″ to 7″ behind a harness, and extend across the warp space. A collar F is recessed to take a spiral spring and is fixed upon D. One end of this spring is made fast to the collar, the other end is similarly united to the loose half G of a claw clutch. The second half G′ of the clutch is fast upon D, and D is vibrated in the following manner: A cam H is fixed upon the picking shaft, and one arm of a cranked lever I rests against its face. The rear arm of I carries an adjustable rod J, whose upper end is fast upon the loose half of G. As H rotates, a rocking movement is conveyed from I, J to G. The coiled spring attached to G and to the fast collar F transmits sufficient energy to rock the shaft D. If by the descent of a dropper A the vibrations of the comb E are arrested, a loom must be instantly stopped. This is accomplished by mounting the driving handle V upon a pin and

passing its base through a slot in a lever L, N, whose fulcrum is a shaft M situated in front of the rocking rail. The arm N is pinned upon a hooked bar O, and O has its

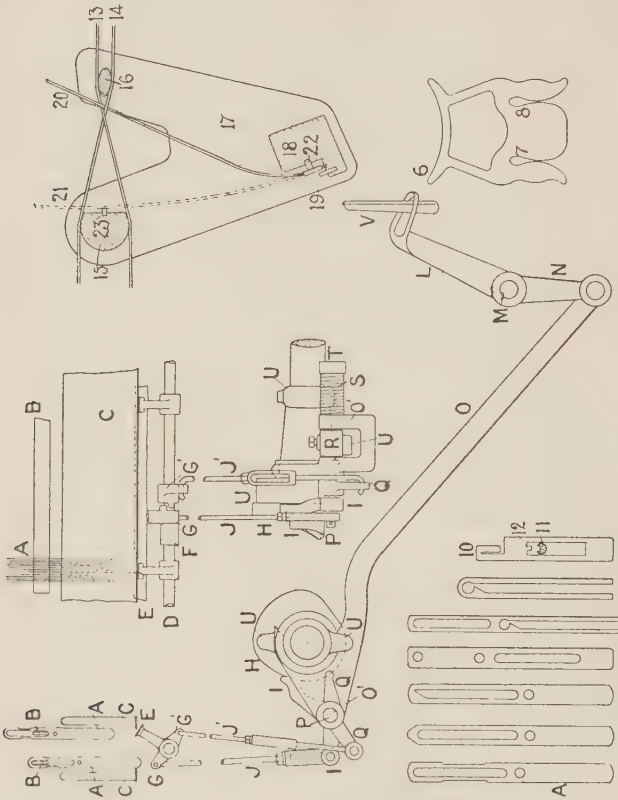


FIG. 246.

hook passed behind, and half round, a ring groove in the boss of H. Beyond the hook, O has a projecting piece O′ in which are bearings for a shaft P. Upon this shaft the cranked lever I is fixed, and a straight

lever Q is loosely mounted. A rod J′ unites the rear arm of Q with the fixed half G′ of the clutch. A short arm R is set-screwed upon P, and beyond R a coiled spring S has its outer end secured in a collar T, which is also fast upon P, but the inner end of S is fixed in the projection O′ of the lever O.

As the cam H rocks the dropper shaft D, an opposite vibrating movement is imparted to the straight lever Q by the rod J′, and the inner ends of Q and R are thereby raised and lowered alternately. So long as the comb E vibrates its full distance, the forward ends of Q, R are carried out of reach of two pieces U, that project from opposite sides of the boss of cam H, and the loom continues in motion. But if a dropper A, from the front line, falls into the path of E, the spring in F yields to the action of the cam H, and R, by engaging one piece U, is pushed back. In receding R takes with it the hooked bar O, thereby causing the lever N, L to free the starting handle V from its retaining notch. In the event of a dropper A, from the back line, falling into the path of E, the spring S yields, the inner end of Q makes contact with the second projection U, and the loom is stopped as before. Electrical connections may be employed to stop a loom in place of the mechanical device described above.

Several drop detectors are shown detached in Fig. 246. In those marked A, 1, 2, and 3, the warp is drawn through the detector eyes before entering a shedding harness and reed. But in 4, 5, and 6 provision is made for placing the detectors over warp threads. In 3, 4, 5, supporting rods are placed beneath a warp, but dirt and fluff are liable to accumulate upon the bars and impede free movement in the droppers. In 6 the detector is supported by two adjacent warp threads, one of which enters the eye

7, the other enters eye 8. In case either thread breaks, one end of 6 descends into the path of a vibrating comb and the loom is stopped. A thin piece of slotted metal has been freely hinged upon the top of a dropper A, and a light rod threaded through all the slots that fall in one line, so that, on the descent of A, the hinged piece will be lifted to locate broken warp. A detector of the type shown at 9 is suspended at 10 from a wire heald, and at 11 a vibrating grooved shaft passes through all the detectors that form one line. As a heald moves from one shed line to another each is, at one point, supported by a warp thread until a fracture occurs, when the tongue 12 falls into the groove of shaft 11 and arrests vibration. So soon as this occurs a loom is stopped.

Detectors occupy different positions in a loom; those represented by A, 1, 2, 3, 4, 5, and 6 are usually placed in a frame behind a shedding harness, but forked detectors such as 4, 5, and 6 may be suspended between lease rods; the latter are then fixed in a frame and a predetermined distance is maintained between the droppers and rods. Detectors in the back line are supported by threads that pass beneath the back rod, and those in the front line are supported by threads that pass beneath the front rod. The warp is itself supported by three round rods; two are outside the lines of droppers, and the third between them.

Breakages in warp being most frequent between the cloth fell and harness, detectors of the types A, 1, 2, 3 are occasionally placed between a harness and slay. But it is then necessary to place a harness an undesirable distance from the cloth fell. Detectors of type 9 are placed in the best position for acting instantly; they have, however, only been adapted for patterns that may be woven with a small number of shafts.

In 1902 A. P. S. Macquisten patented a warp stop motion of original design and application. It is shown in Fig. 246, where 13, 14 are two warp threads; 15, 16 are back and front lease rods respectively, which have their ends secured in two frames 17. An adjustable comb clamp 18 is also secured in 17; it is slotted longitudinally to take a series of wire combs 19, each 1″ long by 5½″ deep. The backs of the combs rest against a metal bar 22, and two warp threads 13, 14 are crossed beween 15 and 16, then one tooth is passed between them. When a loom is in operation the comb teeth are drawn forward by the crossed warp as at 20, but on the failure of one thread a tooth springs back to the position 21, where it makes contact with a strip of metal 23, let into the lease rod 15, and thus closes an electric circuit to operate the mechanism connected with the driving gear, and stop a loom. A breakage is readily located by the position of a wire.

A flexible wire is passed under a screw at one end of the control plate 23, and another wire is similarly placed against plate 22 in the comb clamp 18; these suffice to convey the small current necessary. The electro-mechanical motion which stops a loom is contained in a circular dust-tight casing bolted to the loom frame near the starting handle. It consists of a rod attached to a slay sword for the purpose of rocking a lever fulcrumed in the box. A projection from a slotted portion of the box is situated immediately behind the starting handle and is normally stationary. But on contact being made between a comb tooth and the plate 23, a piece of metal is moved electrically into the path of the swinging lever, and the otherwise stationary projection is pressed forward by the lever to stop a loom.

Weft Stop Motions

Dr. Cartwright quickly realised that a practical power-loom would require many new pieces of mechanism, one of which was an appliance to stop a loom immediately weft gave out, and thus prevent a fabric from being rendered unsightly by cracks. He fixed a swinging staple inside a shuttle, and caused it to be supported in a horizontal position by a thread of weft. When the weft failed, the staple assumed a vertical position, and was caught by a hook near the entrance to a shuttle box. This hook acted through a lever upon the driving belt, and brought a loom to a stand. Dr. Cartwright's plan did not succeed, nor was any striking success achieved by later inventors, until the introduction of the "fork and grid," which C. Gilroy claimed to have invented in 1831. Mr. Osbaldeston, of Blackburn, also claimed the invention, but it was patented in England by Ramsbottom and Holt in 1834. It was improved by Kenworthy and Bullough in 1841, and in 1842 James Bullough added a brake to make its action certain and expeditious.

From the last-named year this delicate and simple device has been an essential adjunct to most looms. It is usually adjacent to a starting handle, and a fork A, Figs. 247 and 248, is placed between a fabric and a shuttle box. Its three prongs are bent almost at right angles to its shank; the shank is also bent in the same direction to form a hook about $\frac{3}{8}$ of an inch long. A fork is free to swing upon a pin, but the prong end is the lightest. In 1903 T. Pickles and B. Blakey patented a fork made in two pieces; the prong section terminates slightly in front of the fulcrum pin, where it is bent at right angles. A second pin supports a shank that is bent at right angles at

both ends. The vertical portion of the fork impinges upon that of the shank, hence any pressure put upon one will tilt the other. The object of this change is to remove strain from a fork pin and thus prevent wear, for a worn pin renders the prongs liable to touch the grid bars.

A fork holder B is fixed by a set-screw to a fork lever C that occupies a horizontal position immediately behind

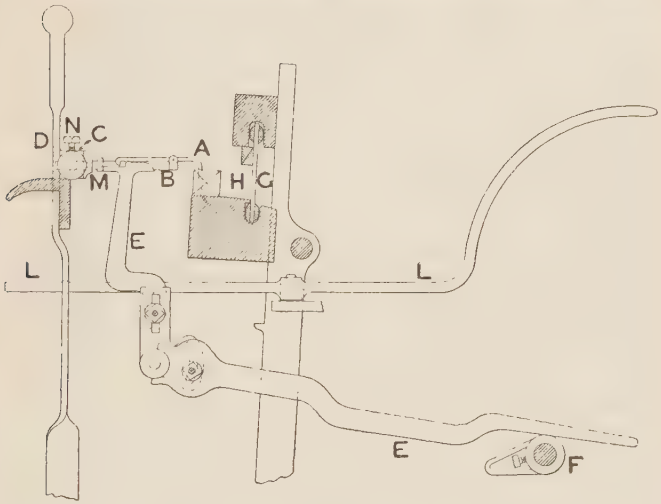


FIG. 247.

a starting handle D, and is hinged at its outer end. The short bend of A rests upon the top of a cranked hammer lever E, which is furnished with a catch capable of engaging the hook upon A, and the lower arm of E rests upon a cam F, on the bottom shaft of a loom. As F rotates, the head of E moves forward on alternate picks. In looms without a bottom shaft, a revolving scroll, see Fig. 196, may be used; in that event a rod from W is connected to the hammer lever E, Fig. 247, to impart the requisite rocking motion.

A metal grid G is fixed vertically, between a reed and shuttle box, with its spaces facing the prongs of A. In 1903 T. Pickles sheathed both the grid bars and the fork prongs with rubber; in 1904 he replaced the metal bars by catgut,—the object of the former change being to prevent the prongs passing the usual distance through

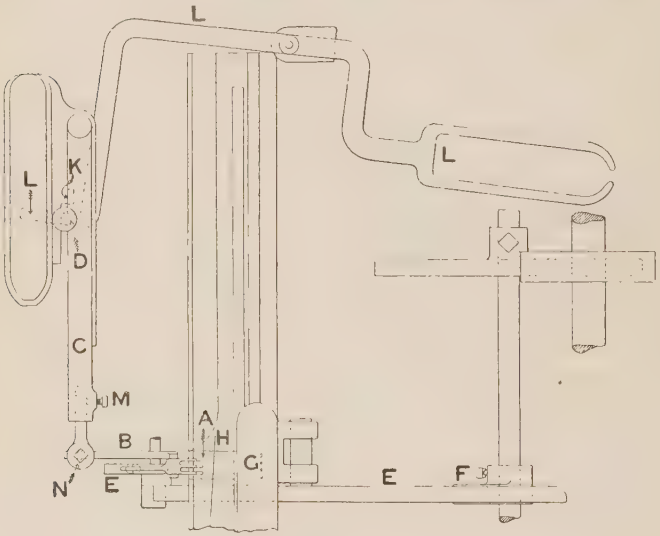


FIG. 248.

the bars, and, therefore, to draw less weft from a shuttle; the latter to render the bars flexible. A weft fork acts as follows: When a slay moves forward and a line of weft H crosses the grid G, the fork prongs are prevented by the weft from passing between the grid bars. By so doing the shank of A is tilted up as the hammer on E begins to advance, thus rendering contact between them impossible. Should a weft be absent the fork prongs pass

through the grid, and the shank remains horizontal. As the hammer moves forward it carries with it the fork, fork holder, and fork lever; the latter pushes the starting handle out of its detent K, and the spring of D, acting through a belt fork L, transfers the driving belt to a loose pulley.

Being placed at one side of a loom this mechanism only feels for alternate picks; but after weft has broken, the cranks should not revolve more than twice before a loom stops. Care is, however, required so to adjust the parts that a loom will stop when weft is absent, and continue running when it is present. To ensure the former, the fork prongs must not touch any part of the grid or race board, and they must be low enough to prevent the weft passing beneath them. Accurate setting is provided for by an adjusting screw M on the fork lever, which allows the prongs to be raised or lowered, and the fork to be moved laterally. A second setting screw N on the fork holder permits of a forward or backward adjustment. A weft thread should lift a fork hook clear of a hammer as the latter begins its forward movement. If a fork passes too far through a grid, there is a risk of cutting the weft; but if it does not pass far enough through, the hook will not clear the hammer. Also, if a shuttle rebounds, the weft is slackened, and will not tilt a fork sufficiently. Any of these things will bring a loom to a stand when it should be running. The lever E should commence to move when a reed begins its backward journey, and when a shuttle is boxed at the fork side, so that if weft is broken the hammer will engage the fork hook and transfer the belt to a loose pulley. If a weft is intact, the fork hook will be kept up until E has moved forward far enough to miss it, and the loom will continue to run. The fork lever C also requires attention;

its movement should be only sufficient to push a starting handle out of its notch. The traverse of this lever is regulated by moving its fulcrum pin nearer to or farther from the fabric. Lateral movement in the slay may cause a fork to tilt when a weft is broken, and permit a loom to continue running.

In order to stop a loom expeditiously, a weft fork has been placed near the entrance to each shuttle box. Also where two wefts are separately drawn from one shuttle, two contiguous forks are employed, but the prongs of one are longer than those of the other, and the wefts are so separated that the short-pronged fork acts upon the upper, and the long-pronged one upon the lower thread.

The Brake

The brake has largely contributed to render the present high speeds possible. Previous to its introduction, from 100 to 120 picks per minute represented the maximum velocity. In some cases a brake is merely an appendage to a weft fork; in others it acts whenever a starting handle is moved; for many purposes the latter type is to be preferred. As ordinarily made, a brake lever, A, Fig. 249, has an adjustable weight B hung upon one arm; the other arm, called the brake clog, is curved and covered on the inside with leather for the purpose of increasing its holding power. This clog is placed immediately below a fly-wheel C, and so governed that both may be instantly brought into contact when a weft breaks, or when a loom is stopped by other means. The weighted end of A is connected by a link D to a tumbler lever E, which rests upon either a bowl, or a curved bracket F affixed to a starting handle. When a loom is put in motion, E is raised by the pressure of F

against its full side, and the link D lifts the heavy end of A sufficiently to move the brake clog out of contact with C. If the weft fork acts, E falls, the brake A bears upon the fly-wheel C, and brings a loom to a stand. A hook on the top of E renders this brake inoperative except when the weft fork lever is drawn forward.

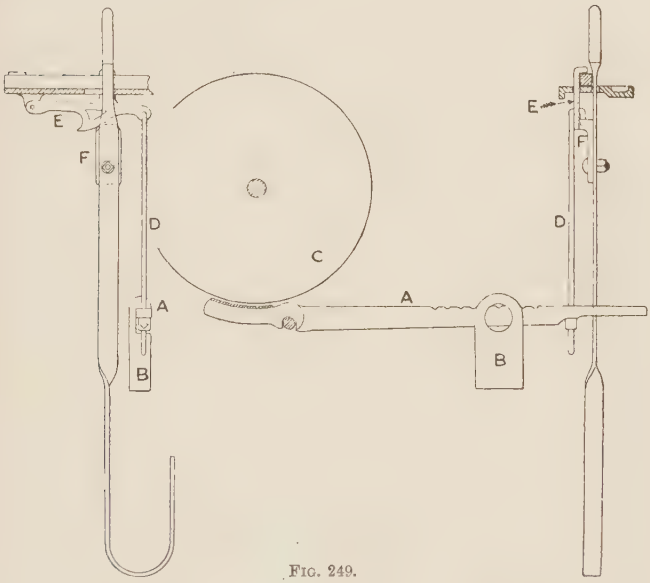


FIG. 249.

An ideal brake has not yet been invented, for, simple as its function appears, its construction is attended with difficulties. A brake when brought into operation should not impart a shock or strain to any part of a loom. It should not reduce the impetus of a slay when the last pick is driven home, but should allow free movement until the driving strap has been moved upon the loose pulley, and

then bring a loom to a stand in the following half pick. If a weft is broken, a loom should always stop with the cranks at the back centres and with a shuttle at the fork side. If stopped by a weaver for piecing broken threads, the top centre is the most convenient place. A brake should not be an encumbrance, or add to the labour of a weaver. In check and other looms, where a pattern must not be broken, means should be provided for holding the brake off while a weaver turns a loom manually to find the proper starting-place.

An ordinary brake puts considerable strain upon the moving parts by acting before the driving strap is upon the loose pulley, and since it takes about one pick to move the strap, the crank shaft is forced against its bearings, the momentum of the slay is checked, and the last pick is not properly beaten home. A brake constantly acts in the same spot, and wears the shaft, bearings, and wheels, and becomes worn itself. When worn a brake permits a loom to stop in different places. The brake shown in Fig. 249 is thus seen to be unsatisfactory in many respects, and attempts have been made to construct a more perfect one. One inventor passes a steel band over a fly-wheel and attaches one end to the brake lever; the other end is made fast to a back brake which swings upon a pin. The band is in contact with about one-third of the wheel's periphery. As this brake lever rises the clogs are removed, as it falls both brakes are applied without a weight, for the moving wheel pulls the brake into action at two places, namely, from the top to the front centres, and about the back centre. In order to obtain a larger braking surface, T. Pickles, in 1894, employed a wheel with a ∧-shaped surface. He also suspended a V-shaped back brake from a pin at the top, and furnished it with a pin near the base

for a slotted arm to pass through. This brake is put in action by the weft fork in the usual manner, but gravitation carries it away from the wheel.

Haythornewaite's brake is constructed on original lines, and contains several good features. The curved arm M

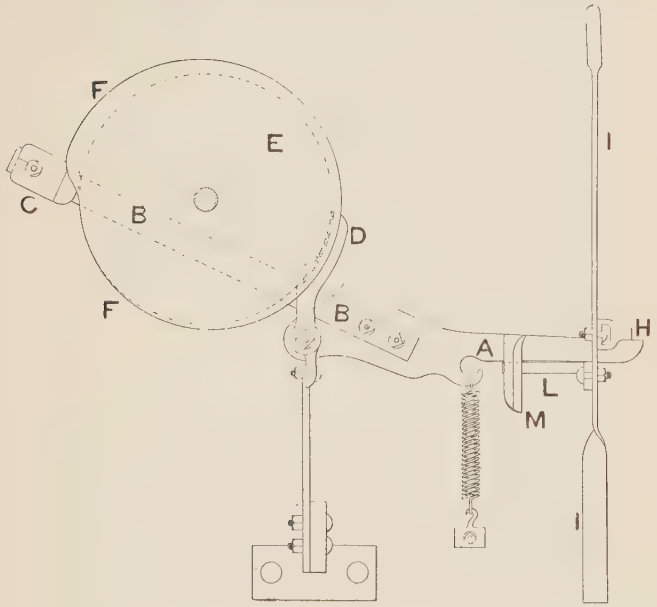


FIG. 250.

of a lever A, Figs. 250 and 251, is pushed up by a finger L on the starting handle I. A piece B is bolted upon A to support a back brake clog C, and a second clog D is also attached to A, to brake in front of the fly-wheel E. A spiral surface F forms part of E, but a groove G runs up the centre, except at one place where it passes diagonally to the outside. When a loom is working, the clogs C, D are

out of contact, but a neb at the extremity of C is in line with the groove G. If a weft fails, the fork lever begins to be drawn back as the cranks leave the cloth fell. The starting handle I is pushed from its detent as the bottom centres are reached. The lever A immediately drops, and the neb of C enters the groove G, but the brake remains inoperative until the front centres are again reached. At this point the diagonal junction between E, F draws the neb of C upon the enlarging periphery of the brake wheel, and a loom is stopped with its slay a little beyond the back centre, and with a shuttle at the fork side

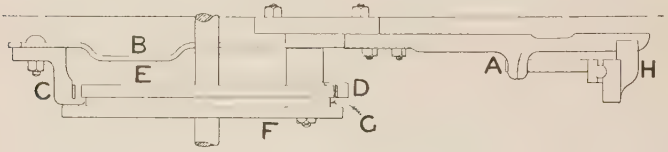


FIG. 251.

As the clog C is pushed back by F it pulls D into contact with the fly-wheel E, and lifts A until its forward end rests against a wedge-shaped fixing H on the starting handle I, where further upward movement in A is checked. Both faces of the fly-wheel are then held as in a clip, without putting unnecessary strain upon the working parts or checking the momentum of a slay in beating up the last pick. A spiral spring steadies A when a loom is working.

For another brake a fly-wheel has its rim broadened at one place. A socket is formed in a brake lever to receive the ball bearing of a clog with a lug at each end. When a starting handle is moved from its detent, the brake clog falls against the narrow part of the wheel; as the latter

continues to turn, the broad part of the rim comes into contact with two clog lugs, and a loom is stopped.

Friction-driving pulleys are being reintroduced to replace fast and loose ones, especially for heavy looms. It is claimed that by their instantaneous action less power is required to brake and pick a loom than with fast and loose pulleys. With the former the driving power ceases as soon as the connections are severed, and immediately the parts are connected, the full force is available to deliver the first pick. But an appreciable time is required to transfer a belt from one pulley to another. In stopping a loom, the belt and brake are opposing each other. In starting it, only a portion of the belt is upon the fast pulley when the first pick is delivered.

The Centre Weft Fork

A side fork is unsuitable for pick-at-will looms, because several shuttles may be driven in succession to the fork side, and if only one weft is intact the loom may continue to run. This defect increases with the number of shuttles in use. With a view to its removal, a fork has been placed in the centre of the reed space and made to feel for each pick. But at a high speed excessive vibration renders its action unreliable.

As made by Messrs. Hutchinson and Hollingworth, a centre fork has a transverse groove A, Fig. 252, cut in the slay B, to permit the prongs of a fork C to sink below the race board. A plate D, screwed upon the slay front, supports both C and a cranked lever H. The fork C consists of two prongs and a holder E, F. Its prongs are made from reed wire, are placed edgewise in two parallel saw slits in the holder, and fixed in position by a

screw. A conical centre is sunk into each extremity of the holder, so that two adjusting screws G may support it. On the lower side two downward curves E, F put the fork under more or less positive control; the former enables it to be

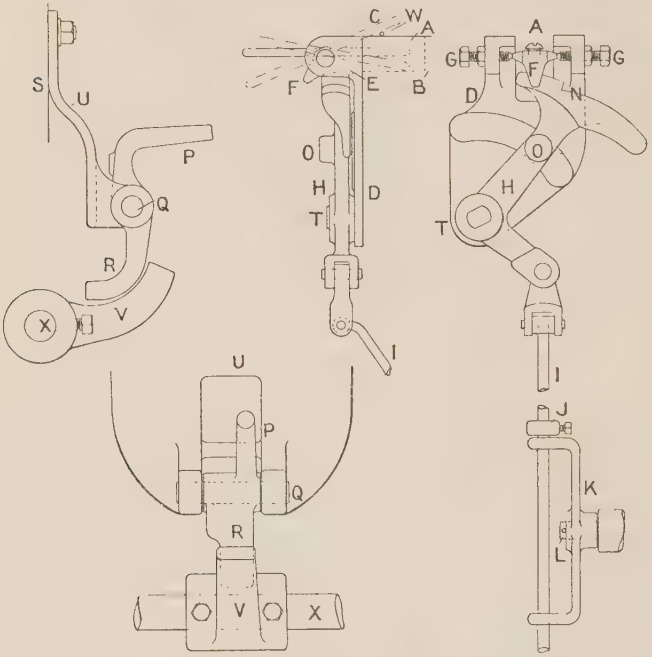


FIG. 252.

lifted and the latter causes it to be partially drawn down. The curves E, F are acted upon by a cam shaped head on a cranked lever H, which is centred at T upon the plate D. The curved upper edge of H lifts E, and an outward swell on the front edge of H draws F down. The lever H has a thin rod I hinged upon it. I passes freely through holes

in the upper and lower flanges of a forked guide K, and K is free to swing upon a stud L, in a bracket attached to one of the cross rails. When a slay is moving into picking position an adjustable stop hoop J, set-screwed upon I, rests upon the upper flange of K. Continued backward movement in a slay carries the lever H closer to the forked guide K, and therefore the rod I assumes a position which approximates to the vertical. On contact being made between K and the hoop J, the rod I swings the lever H until its cam surface bears upon the fork holder, and lifts the prongs high enough to permit a shuttle to pass beneath them. Immediately a slay begins to move forward the rod I falls through the holes in K by gravitation, and draws H with it. If weft is absent as the prongs descend, the piece E remains in contact with the upper edge of H until a notch N is reached, when further movement in H is stopped. A projection O, on the lever H, is then opposite a dagger P, which is centred at Q upon a bracket U on the breast beam S. A slay moves O into contact with P, turns the latter upon its centre Q, and a lower arm R depresses a curved arm V upon the starting handle shaft X. By this means the shaft X oscillates, and the driving belt is transferred to the loose pulley in the usual manner. If, on the other hand, the prongs of C are arrested by weft W lying across the gap A, the fork is prevented from falling farther until the notch N has passed far enough beyond E, for the tips of the prongs to be drawn from the weft by an advancing slay. C then drops to the bottom of the groove A. But meanwhile the stop O has passed beyond the dagger P and the loom continues in motion. Centre forks are met with under various modifications; for instance, a fork may be rocked by a connecting rod fastened to the

breast beam and to the fork. Then as a slay falls back the fork is lifted; as it moves forward the fork falls. A centre fork requires careful setting, and formerly, if the warp and weft were thin and open, the weft was liable to be looped beneath a fabric by the prongs. This defect has been considerably reduced by placing the fork under more positive control, and, in silk looms, by inserting a grid in the gap made in a slay.

PART XX

MECHANISM FOR GOVERNING THE WARP

Since the year 1786 the question of controlling a warp efficiently has received its full share of attention, but failure has followed the efforts of hundreds of inventors who have essayed the problem. The causes of failure are various, for the problem is a many-sided one. A warp-delivering motion should so act upon the threads that an equal strain will be maintained whether a shed be open or closed, and irrespective of the length of warp upon a beam. There should be no necessity for manual adjustment from start to finish of a warp. The warp should be positively supplied in lengths that exactly correspond with those drawn away by the taking-up roller. The mechanism employed should neither be unduly complicated nor liable to become deranged.

From the latter half of the eighteenth century two conditional methods have obtained, namely, rigid and vibrating warp beams. A rigid beam had a ratchet wheel

secured upon one end, and a pawl, hinged to the loom framing, rested in the teeth of the ratchet to hold the beam securely. After weaving 2″ to 3″ of cloth, the weaver pulled a cord attached to the pawl to liberate the wheel. He then proceeded to draw a length of warp forward without leaving his seat. The defect of this plan consisted in putting an increasing strain upon a warp, for every weft thread inserted, so long as a pawl occupied a fixed position.

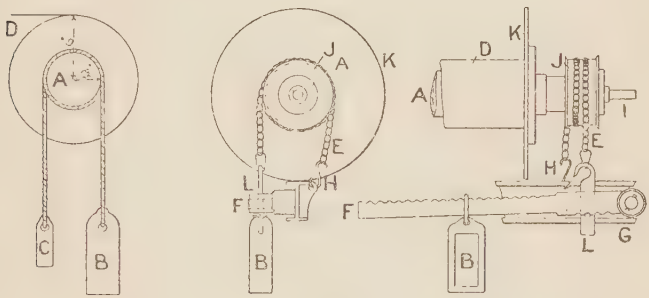


Fig. 253.

About the year 1788 a weaver named Clarke introduced a contrivance that increased the productiveness of a loom, and, in some respects, governed the warp more effectively than heretofore. He coiled two ropes several times round opposite ends of a beam A, Fig. 253, and fastened heavy weights B to the outer, and light balance weights C to the inner ends of the ropes. This allowed warp to be drawn from a beam whenever a taking-up roller was actuated. The control is superior to rigid appliances, because ropes and weights reciprocate with the shedding motion, for when a shed opens, warp is drawn from a beam, and when it closes, any surplus length

is wound on again. But ropes and weights do not keep an equal tension upon a warp in all its varying positions. A change occurs at every revolution of a beam, caused by the withdrawal of a layer of yarn from its periphery, without altering its circumference where the ropes act. To rectify this would necessitate a reduction of weight in proportion to the decreased diameter of the coiled warp. Thus: if the radius of the beam A, Fig. 253, is $2\frac{1}{2}''$; that of the warp D is $6''$; and B weighs 100 lbs., then if warp is drawn from D until its radius becomes $5''$, a weight of 83·3 lbs. must be used to maintain an equal tension $\therefore 6 : 5 :: 100 : 83{\cdot}3$. Clarke's appliance in a slightly modified form is found on nine-tenths of the cotton looms now in use.

One alteration has been made to prevent the weights B from settling upon the floor. For stout fabrics it consists in removing the balance weights C, and fastening ropes or chains E upon hooks on the framing as at H. For light goods, ropes or chains are attached to flat springs similarly situated. Instead of causing the weights B to act direct, their efficiency is increased by suspending them from simple or compounded levers as at F, and uniting the ropes, or chains and levers, as at L. But this renders a beam less sensitive to movement in the shedding harness, and less capable of taking back any excess of warp than where balance weights are used.

In order to cause a letting-off motion to work satisfactorily, many points must receive careful attention. Of these the beam is one. Beams A are principally made of wood, of which there are two varieties, viz. solid and built; in both dry sound timber should be used. An iron hoop is inserted into each end of a solid beam; holes are drilled, filled with liquid glue, and bearded gudgeons,

about 1″ square in section, are driven in. The beam and its gudgeons are then turned to a uniform diameter; the former varying, according to the material used in its construction, from 4″ to 6″, and increasing by $\frac{1}{4}$″; the latter is from $\frac{7}{8}$″ to $1\frac{1}{4}$″. A built beam consists of a series of pulleys mounted upon a square shaft; these are covered with wooden lags, and turned. It is considered superior to a solid one, because the shaft renders twisting a rare occurrence. Beams are also made of cast or wrought iron and seamless steel tubes. The latter are light, and metal beams of all kinds are liable neither to twist nor split. They may be made with open ends and supported in cup brackets, or solid iron plugs may be cast with the gudgeons I, and the tubes shrunk on the plugs and riveted.

Cast-iron ruffles J prevent ropes and chains from channelling a beam; they must have sufficiently smooth surfaces to allow ropes or chains E to slip regularly. Smooth or corrugated iron or steel flanges K, from 12″ to 21″ in diameter, are fixed upon all beams intended for use in power-looms. They permit warps of great length to be wound on without risk of entangling the outside threads. Flanges are secured upon beams in various ways: A steel one may have a malleable iron boss bolted upon it, and be fastened to the beam by means of a clamp. Other flanges are cast in two sections, and clamped together upon a beam. But many are cast-iron, and simply screwed upon a beam.

A warp beam is supported in brackets bolted to the loom framing, and must be parallel with the back rest, the breast beam, and the taking-up roller. Unless a warp is wound upon a beam with an even tension, faulty cloth will be made. No definite rule can be given for weighting, nor for the length of warp exposed between

a beam and a harness; both vary with circumstances. Generally a warp is held as tight as its strength will allow without giving the fabric a harsh feel or breaking the threads. If the strain is excessive, great force will be needed to open a shed, and the picks will not be driven close together. If the strain is insufficient, slack warp will permit one weft thread to ride upon another and form ridges in a cloth. Too much or two little warp may be subjected to the pulling action of healds; in either case unnecessary wear and tear results; in the former, because it is pulled too frequently before being woven; in the latter, because too great a tax is put upon its elasticity. From 20″ to 24″ is enough for looms making light fabrics, but 36″ to 56″ may be required in heavy looms.

Chains E are often superior to ropes for weighting warps, as the tension is more regular, and the cost of keeping them in good condition is less. The amount of friction produced by coiling ropes round beam ruffles depends largely upon their condition. New ropes possess greater holding powers than old ones; and ropes made from different fibrous materials give varying results. The condition of a ruffle also affects the tension put upon a warp; but if a given rope is coiled round a beam A, Fig. 253, and has a weight B and a counter weight C attached to opposite ends, by doubling the weight of C twice as much weight will be needed at B to maintain an equal pull; for friction is in proportion to load.

An alteration made in the number of coils of rope upon a ruffle will produce marked changes. If a rope is twisted once round a beam and weighted, theoretically 1 lb. at C will be slowly pulled up by 3 lbs. at B. If the rope is lapped twice round, 9 lbs. will be required at B to lift 1 lb. at C. With three laps 27 lbs. will be needed at B to lift C,

and with four laps 81 lbs. will be necessary to perform the work. This is equal to the first, second, third, and fourth powers of the coils, or $1 = 3^1$, $2 = 3^2$, $3 = 3^3$, $4 = 3^4$.

Perry, in his *Practical Mechanics*, gives the following results of actual tests with a 1 lb. counter-weight :—

Laps of Rope on Ruffle.	Weight in lbs. required to slowly raise the Counter.
$\frac{1}{2}$	1·6
$\frac{3}{4}$	2·1
1	3·0
$1\frac{1}{4}$	4·0
$1\frac{1}{2}$	5·1
$1\frac{3}{4}$	6·6
2	8·0
$2\frac{1}{4}$	10·0
$2\frac{1}{2}$	14·0
$2\frac{3}{4}$	20·0
3	23·0
$3\frac{1}{4}$	30·0

The table shows a divergence from theory, but it demonstrates the utility of the rule give above.

There is a point beyond which additional laps will not be beneficial, and it is reached when regular slipping ceases, for the weights B are then wound up and the counters C sink to the floor. If, when the inner end of a rope is fixed to the loom framing as at H, a weight B is lifted, that end will slacken, and slipping will occur, but of so irregular a nature as to be useless to a weaver. It often happens that more than three coils are ineffective. Instead of increasing the coils it is desirable to increase the weights of the leverage.

The rope and lever tension device is simple but unmechanical. When tested by the conditions stated on p. 500, it is found to be incapable of maintaining an

equal tension, either as sheds open and close or at different parts of a warp. An attempt is, however, made to approximate to a uniform tension during shedding by employing a vibrator, which moves in to slacken a warp as a shed opens, and out to tighten it as a shed closes. But the regulation of friction from one end of a warp to the other is left to the weaver, who reduces the weight on F as the diameter of the warp beam diminishes. Vibrators are not equally useful for all classes of fabrics, or for all shedding motions. They may be especially useful where all the warp is moved for every pick, as in plain and centre shedding. They are often essential in looms furnished with a positive warp-delivering motion. But for stationary bottom and open shedding a vibrator is of less use, since it must slacken or tighten all the warp threads simultaneously, whereas only those that move require easing. When plain and centre shed looms are without vibrators, the rear ends of the weight-ropes or chains are attached to springs, which to some extent reciprocate with the shedding movement. Otherwise the weight-ropes are connected to fixed hooks H. A vibrator will then give satisfactory results, provided the shape and throw of its cam are derived from the shedding lift.

Ropes and weights do not fulfil the second condition, for instead of a warp being delivered positively, it is pulled from a beam as required by the shedding, beating-up, and taking-up motions. The third requirement is admirably met, because nothing capable of doing the work can be simpler or, when once adjusted, less liable to become deranged.

The so-called positive let-off motions include automatic tensioning appliances; also mechanisms which deliver a warp positively, but require weights or springs to

maintain a fixed tension upon the threads after they leave a beam. In most of these, positive and conditional parts work in unison, but without direct connection with the taking-up motion. Other let-off motions not only deliver the warp but draw away the cloth positively.

From a multitude of devices it is only possible to select typical examples from each class. Yet from these a general knowledge may be obtained of the directions in which inventors have worked. Charles Schilling of New York claims to be the inventor of a motion belonging to the first-named class. He uses weights B and smooth levers A, Fig. 254, but fastens the weights to an endless rope C that passes over guide pulleys D, E and round a rope wheel F. A pinion G is compounded with F, and its teeth gear with those of a rack H suspended from a presser lever I. The fulcrum of I is at J, and a movable weight is placed upon J at K. Above the rack H a presser bears against the under side of a warp, and as the latter is drawn away H ascends, moves the pinion G, the wheel F, the rope C, and the weights B. Since the rope C is crossed, any movement imparted to it will carry each weight B towards the fulcrum pin of its lever, and diminish the pull upon a warp beam in proportion to the reduced diameter of the warp. This motion is neither unduly complicated nor difficult to adjust. When a full warp is put in, the presser is forced down and the weights move to their proper places. If necessary, the weights can be removed during weaving, but they must be put back in the same places. Its defects are: that a warp is not delivered, but pulled off; that the presser prevents a beam from taking back any excess of warp drawn away; that it does not maintain an even tension during shedding; that the form of the presser is liable to cause the surface of

a beam to become irregular. But a roller extending from flange to flange would remedy the last-named defect.

In 1875 Messrs. Hanson and Crabtree patented an automatic tension motion, in which a beam A, Figs. 255 and 256, rests in leather-covered cup brackets B, B. A cap is held upon the top of an iron hoop on A by means of a flat spring C, and is pressed down by a screw K. The pressure is reduced at every revolution of a beam by a peg D in a beam hoop. D engages a star wheel E, and

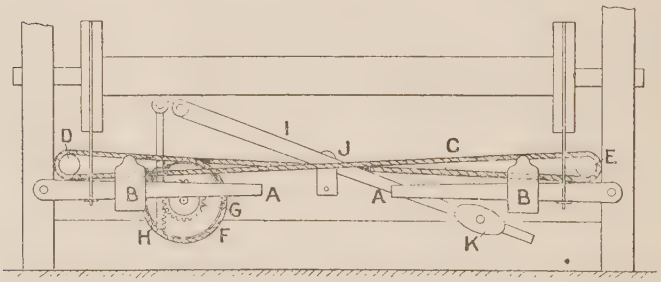


FIG. 254.

by moving it one tooth, sets in motion the wheels F, G, H, the worm I, the wheel J, and the screw K, thus slightly reducing the compressing force of C upon B. Different wheels F, or H, are used for different warps and fabrics.

A motion belonging to the second class is made by Smith Brothers. It consists in fixing a worm wheel A, Figs. 257 and 258, upon one end of a warp beam to gear with a worm B. The latter is secured to the bottom of a short vertical shaft, and a ratchet wheel C is secured to the top. Upon this shaft a bent letting-off lever D, F is loosely mounted. On the arm D a pawl E is hinged, to take into the teeth of C. A spiral spring, hooked into D, and also

into a bracket on the framing, keeps the lever in one position when not otherwise controlled. A rod G is hinged upon a slay sword, its rear is slotted, bent at right angles, and furnished with an adjusting screw. A screwed stud in the arm F passes through the slot in, and its head supports, G. Each forward stroke of a slay imparts sufficient movement to G, F to cause the pawl E to drive

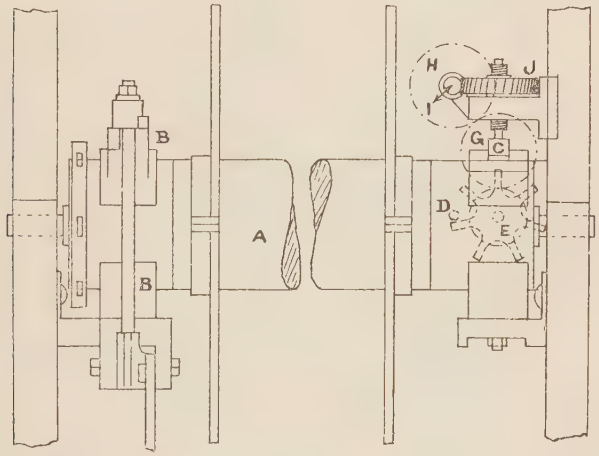


FIG. 255.

C one tooth and move the warp beam. But a tooth taken when a beam is full will deliver a greater length of warp than when a beam is nearly empty. For this reason conditional parts are added to regulate the supply. These are: a shaft H, which carries a three-armed lever I, J, K near one extremity, and a two-armed lever, I, J, near the other. I, I support a warp roller L, and J, J two weighted stalks M, M, while K is united to the lever D, F by a slotted rod N and a stud.

A warp passes inside the shaft H, and over the vibrator

L to the harness and fabric; but the weights upon the stalks M keep it under a constant tension. The ratchet C, if moved one tooth for each revolution of the cranks, would deliver more warp than the taking-up roller requires. Should this occur, the roller L is pulled back by the weights on M, and the rod N is pushed forward by the arm K until a stud in F impinges upon the inner end of the slot in N. The spiral spring is then unable to draw the pawl E far enough back to take a tooth in C, and letting-off is suspended until L regains its normal position. For heavy work, a brake band is drawn by an advancing slay against a ruffle on the shaft H, to prevent L from vibrating during beating up. A greater strain is put upon the yarn in an open than in a closed shed.

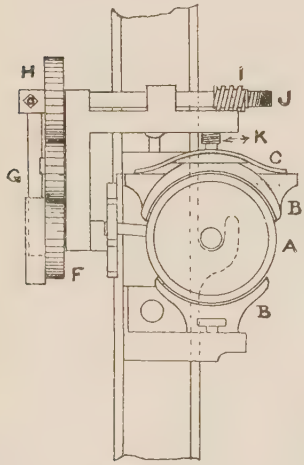


FIG. 256.

In 1892 R. Wilby removed the stalks and weights M, and in their stead employed the upward thrust of springs to regulate the inward movement of the vibrator L. He also altered the positions of the parts, but left them essentially as above named.

Messrs. Hutchinson and Hollingworth have developed a letting-off motion which also belongs to the second class. It is constructed as follows: Upon the slay sword a link B, Fig. 259, forms a connection with a three-armed ⊥-shaped lever C, whose fulcrum is at D. Each horizontal arm of C terminates in the segment of a bevel wheel,

and the teeth of C engage corresponding segments on two cranked levers E, F. These levers are loosely mounted upon a letting-off shaft G, and are situated on opposite sides of a ratchet wheel H, secured upon G. In the upper arms of E and F two pawls I, J are respectively

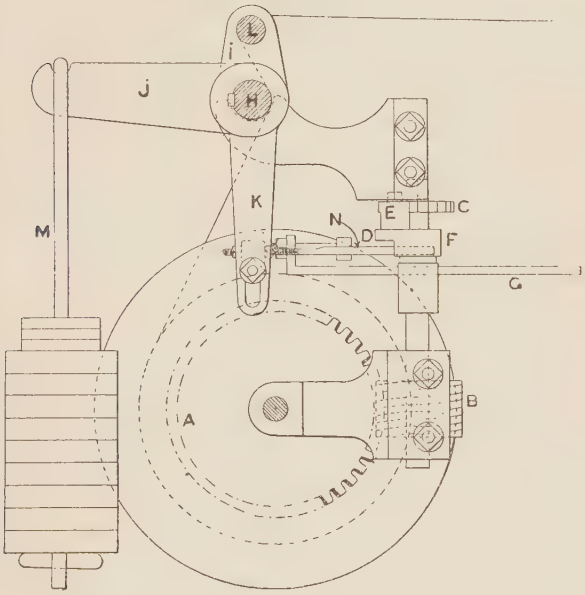


FIG. 257.

mounted. As a slay moves the segments on C to and fro an alternate movement is imparted to the pawls I, J, and this causes one to drive H at each forward, and the other at each backward, swing of a slay.

At the rear of the letting-off shaft G a worm K engages a wheel L on one end of a warp beam M. At the front of G a flanged wheel N has a brake band upon its

surface to prevent overrunning. The warp from M is led over a vibrating roller O, thence through the shedding harness and reed to the taking-up roller. The ends of O are supported in the cup-shaped terminals of two cranked levers P, only one of which is shown. One lever P moves upon a stud Q; its straight arm supports an adjustable rod R, and R is attached to a weighted lever S, whose fulcrum is at T, and whose action is to draw O outward; but the extent of such movement is limited by an adjusting

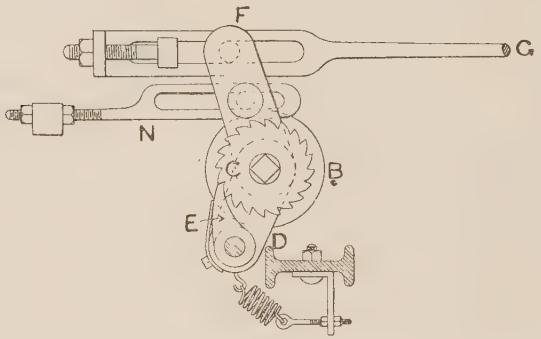


FIG. 258.

screw 2 placed beneath the straight arm of P. The second lever P is furnished with corresponding parts Q, R, and 2, but a link connects P, P in order to render the weighted lever S equally efficient at both ends of a loom. At U one lever P is provided with a regulating screw that impinges upon a lever V; the latter moves upon a pin W; at X it is connected to a cranked lever Z by a rod Y, and Z is loosely mounted upon the letting-off shaft G. To the lower arm of Z a shield 1 is affixed for the purpose of regulating the supply of warp. In case of excessive delivery the shield is interposed between the

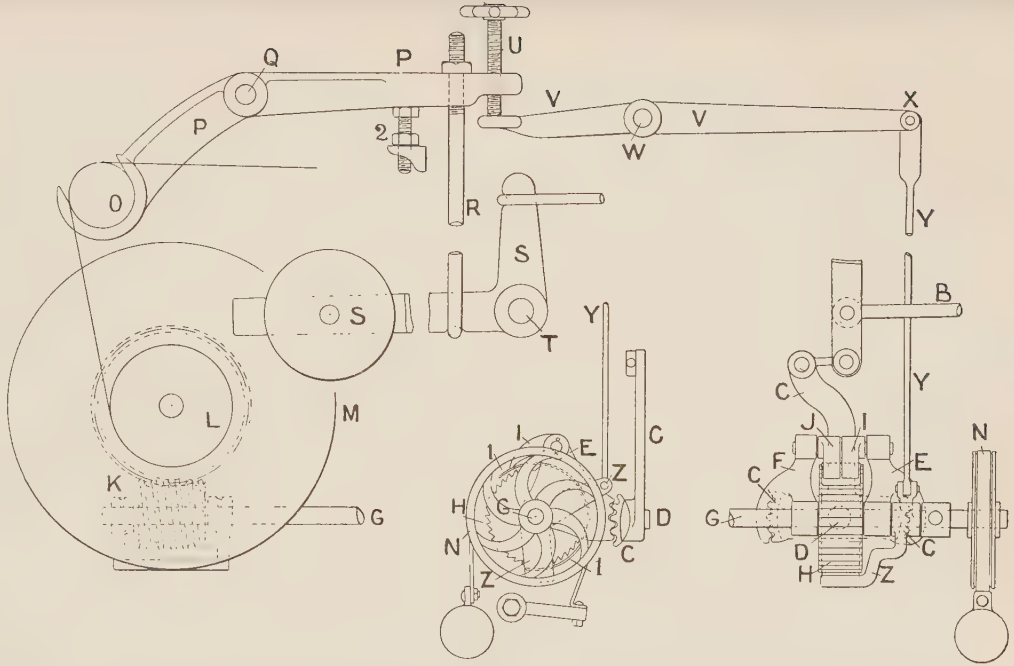


Fig. 259.

pawls I, J and the ratchet H. When this occurs, I, J merely vibrate upon the shield, and all delivery ceases. But 1 also permits warp to be given off in the following manner: The forces exerted in shedding, beating-up, and taking-up tend to draw the vibrating bar O inward, a tendency which is resisted by the weighted lever S acting through the rod R. Immediately the force of S is overcome, the adjusting screw U rises with the horizontal arm of P, and permits the lever V to vibrate. In falling, the long arm of V imparts movement to the rod Y and rocks Z, thereby withdrawing the shield from between the ratchet and pawls; the latter then give motion to H and deliver warp.

If the pawls I, J are set to deliver sufficient warp from an almost empty beam, they will be nearly inoperative when a beam is full, but will automatically increase in effectiveness as a warp is uncoiled. By this means the conditional parts limit the action of the positive ones, and form a reliable combination. If two warp beams are necessary, the above-mentioned parts are duplicated.

A letting-off roller may be mounted in two arms of a weighted lever and set to bear against a warp. A cam on the bottom shaft then depresses another arm of the same lever, and from this arm a connecting rod operates a pawl in a similar manner to that shown at E, Figs. 257, 258. The nearer such a pressing roller approaches the axis of a warp beam, the more the tappet depresses the lever, and the farther the ratchet is driven.

In 1882 George Keighley devised a self-contained let-off motion, in which the beam is only weighted to prevent a warp from overrunning. After a warp leaves a beam it passes over a heavy, cloth-covered pressing roller A, Fig. 260, under a measuring roller B, having the same circumference as the taking-up roller Q, viz. 15″, and over

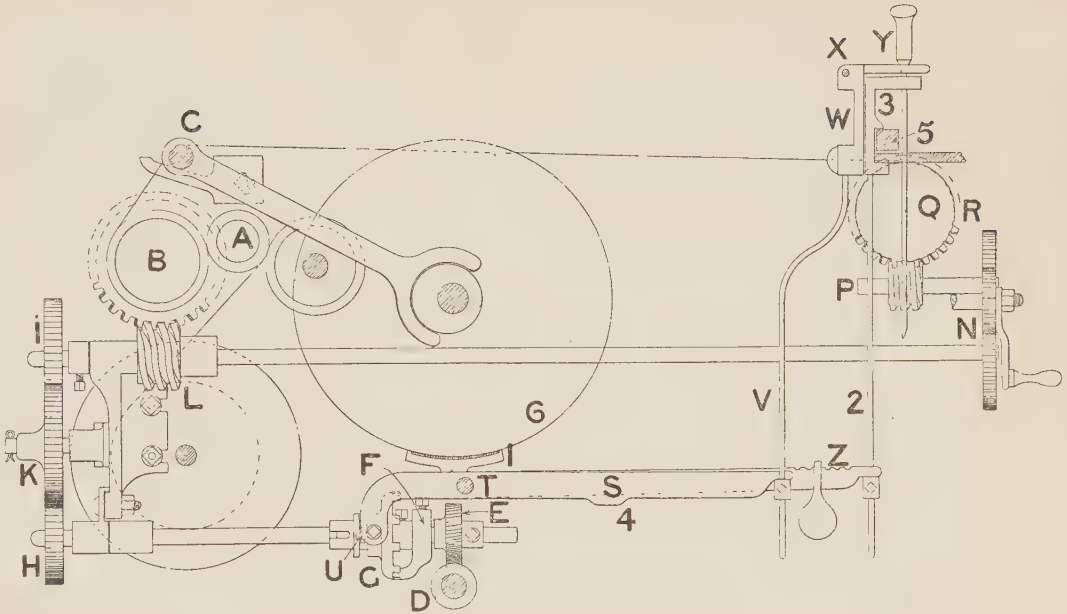


FIG. 260.

a vibrating bar C, to the cloth roller. The roller A is placed between B and two supporting pulleys that allow A to gravitate towards B, and thus hold the warp threads securely.

The parts are driven by a worm D, on one end of the bottom shaft, for D engages a wheel E upon a clutch shaft. Slightly in advance of E, a bracket F carries a flattened projection into contact with one of ten teeth on the side of a disc clutch G. When a loom stops, G slides backward upon a key-way, to disengage the letting-off and taking-up parts. G is traversed laterally upon its shaft by a pin U in lever S, which enters a ring groove in the clutch G. A rod V connects S with a three-armed lever W; its horizontal arm touches the starting handle Y, and is hinged at X, so that by turning it up to the perpendicular, a loom may be set in motion without delivering warp or drawing cloth forward. If this arm is left horizontal, when Y is shifted to its detent, W rocks, lifts V and S, and by sliding G into contact with F, all parts of the letting-off motion begin to act. Should the weft fork stop a loom, the disc G immediately moves away from the single tooth F, but F continues to move until a loom becomes stationary. After starting a loom, and before more cloth is drawn forward, the single tooth F must travel until it again makes contact with G. Cracks are thus prevented, for it takes on an average from two to three picks for F to move from tooth to tooth in G. A piece 4 on the lever S passes beneath a weighted brake lever Z to lift Z with S. But Z is free to rise alone; it carries a brake clog 1 at its inner end, and is connected by a rod 2 to a tumbler lever 3, which rests upon the weft fork lever 5, hence, when Y is moved outward, Z rises with 2, and the clog 1 leaves the periphery

of a fly wheel 6; the opposite movement of Y causes the brake to act. The measuring roller B is driven from the clutch shaft by a wheel H, that contains 15 teeth if the teeth in a wheel I equal the number of picks per $\frac{1}{4}$ inch in a fabric. If H has 30 teeth, they equal picks per $\frac{1}{2}$ inch. If 45 teeth, they equal picks per $\frac{3}{4}$ inch; and 60 teeth give the picks per inch. The wheel I is changed when alterations have to be made in the number of picks; it is attached to the rear end of a side shaft and is rotated by a carrier K. A worm L drives the measuring roller B, and another wheel on the forward end of the same shaft drives, through a carrier N, the taking-up roller wheel, which contains 100 teeth. The latter is fixed upon a short shaft P, whose axis is at right angles to the taking-up roller Q, and is compounded with a worm which takes into the teeth of a worm wheel R, on Q.

More than one yard of warp is required to weave one yard of cloth, but the exact amount varies with the weave and with the thickness and closeness of the warp and weft. It is almost impossible to ascertain by calculation the allowance for contraction; in practice this is determined by experience. Assuming the percentage of warp-contraction has been obtained, the wheel on the forward end of the side shaft must have one tooth less for every per cent of contraction than the wheel on P.

The parts described above secure a regular delivery of warp, and a constant tension results from making the outlines of the shedding and vibrator tappets similar in curve but dissimilar in throw. The following experiment was made in order to ascertain to what extent the inventor had succeeded. A thread was passed between the rollers A, B, over the vibrator C, through the healds and reed, and over the taking-up roller Q. This thread terminated in

a light weight, and was permitted to hang loosely. On moving the healds up and down the weight remained stationary, hence it was concluded that the tension was constant. This device contains many costly parts, and more time is required to gait a new warp than when a tension motion is used.

An increase of moisture in the atmosphere causes warp thread to contract in length, and when under positive control they are held rigidly by the cloth and warp beams. If under such conditions a loom is left stationary for a considerable time, the tensile strain upon the threads as they contract is often sufficient to cause fibre to slip upon fibre, and a large number of breakages to occur before the warp thus exposed can be woven up.

PART XXI

AUTOMATIC WEFT-SUPPLY MECHANISM

From the time when steam and water replaced manual power for weaving, efforts have been almost ceaselessly directed towards the attainment of increased productiveness in power-looms. For many years inventors endeavoured so to improve loom mechanisms that higher speeds might be possible, or more looms be allotted to each weaver. But a time arrived when the limits in both directions appeared to be within sight. Other schemes were then resorted to. Existing methods of supplying looms with weft were known to be unsatisfactory in proportion to the coarseness of the material to be used. Enlarging the storage capacity of a shuttle offered a partial

solution, but it was recognised that large shuttles required sheds of corresponding dimensions, and this entailed a higher percentage of warp breakages. Radical changes were inevitable if production was to be considerably increased, or if one weaver was to attend to a larger number of looms. Once such ideas became fixed, the problem was attacked from many sides. Some attempted to convert a shuttle from a storer of weft to a carrier of sufficient weft for one or two journeys only, and to draw from an external supply. Since a carrier could be considerably smaller than a shuttle, small sheds, and a reduced strain upon the warp would follow. Others attempted to give shuttles a continuous instead of an intermittent motion, and to cause several of them to move through a warp simultaneously, at fixed distances from each other in a circular path. These inventions require a warp to be divided in advance of, and closed behind, each shuttle, also that the weft deposited amongst the warp shall be beaten home before the arrival of another shuttle. But their details have not been sufficiently perfected to render the looms practicable.

Two principles are involved in the mechanisms now prominently under the notice of manufacturers. One consists in retaining shuttles of the usual type, and means are devised for ejecting a shuttle containing an exhausted spool or cop, and automatically inserting a fully charged shuttle. The other scheme consists in ejecting a spent spool or cop from a shuttle and replacing it with a full one. Neither principle is new, for in 1840 Charles Parker patented a method by which a spent shuttle was automatically ejected and a loaded one inserted. This was followed in 1852 by a patent granted to William Newton for a communication describing a different method of

compassing the same end. Automatically changing a cop or pirn dates from 1857, in which year Patrick M'Farlane patented a device for placing a cop in a case and inserting and ejecting the cases when necessary. In 1860 Thomas Ingram patented another method, and in 1861 John Leeming modified Ingram's invention.

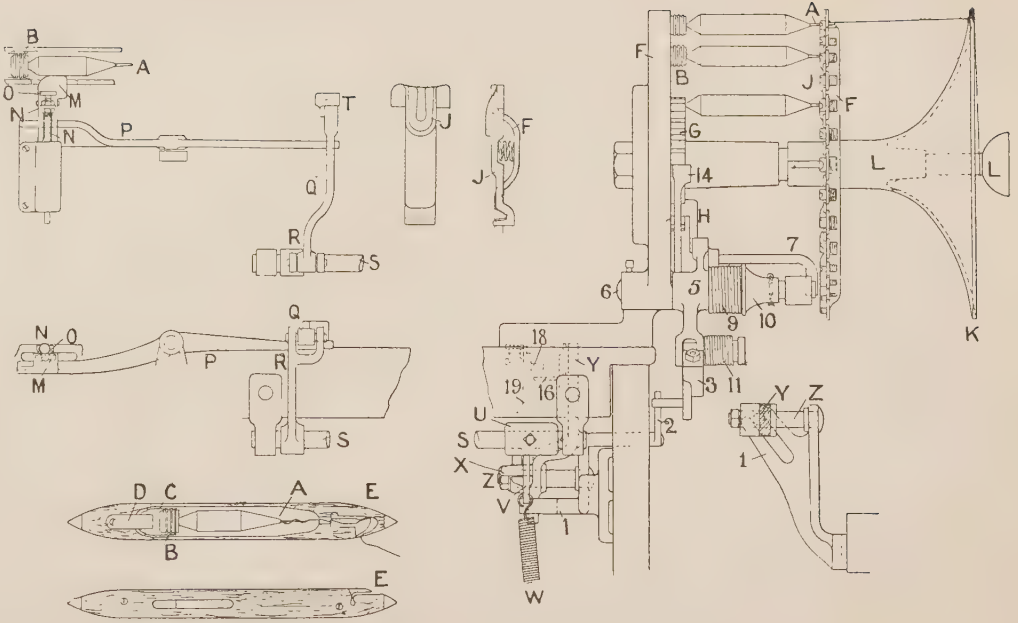
Since 1894 many shuttle-changing devices have been exhibited, some of which embodied the ideas of older inventors, others were developed upon original lines. Original shuttles have been inserted and ejected in front, behind, above, and beneath single shuttle boxes; they have been fed in at one end of a loom and ejected at the other end. Drop and revolving boxes have also been employed to assist in moving an empty shuttle away from a picker and a full one into working position. Subsequently the empty shuttle was ejected from its box and replaced by a full one. While effecting changes in shuttles, looms have been worked at their normal speed, at a reduced speed, and have been automatically stopped and started before, and after, a change. Changes have been controlled from a weft fork; from a feeler that acts when the weft supply is almost exhausted; also from a pick counter which effects the change after a predetermined number of picks have been drawn from a shuttle. The parts that effect the changes have been mechanically and electrically controlled.

Spool-changing devices are less numerous than shuttle changers, but they are more extensively used, probably because it is easier to change the contents of a shuttle than to change a shuttle, for shuttles are specially liable to injury during the changing operation; it is also more difficult to adjust shuttle boxes to many shuttles than to one.

The Northrop Weft-Changing Mechanism

The cop changer invented by J. H. Northrop, and patented in the United States of America in 1894, marked the beginning of far-reaching changes, which include the reorganisation of the preparation and weaving departments of textile works, and possibly that of spinning mills also. So successful has this invention proved that approximately 350,000 of these looms are now in operation.

This device has as its central and most original feature a self-threading shuttle, without which other parts of the loom would be of little value. Instead of a tongue, the shuttle is furnished with a series of movable skewers A, Figs. 261 and 262, whose metal heads are severally covered with a sheath of wood secured by three annular rings B. A forked clip C, with separable spring arms, is fixed at the rear of the weft space in a shuttle; in each of its prongs four vertical grooves are formed to receive the rings B. The diameter of a head of A is greater than the space between the prongs of C, therefore, if a skewer is pressed into C, its prongs will open, B will enter the grooves in C, and the prongs will hold A securely. An inclined directing plate D embraces C, and assists in guiding a skewer into position. After a loaded skewer has been inserted the weft must be automatically drawn into the shuttle eye. This is effected by a brass threader E, which is sunk into the shuttle near the front tip. Along the top of E a diagonal slit communicates with the shuttle eye. For the first pick, the weft enters the slit and goes beneath a downward curved lip at the entrance to the slit; and also beneath the front edge of the threader. For the second pick, the weft is sharply deflected and travels downward through a clearance space between E and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9
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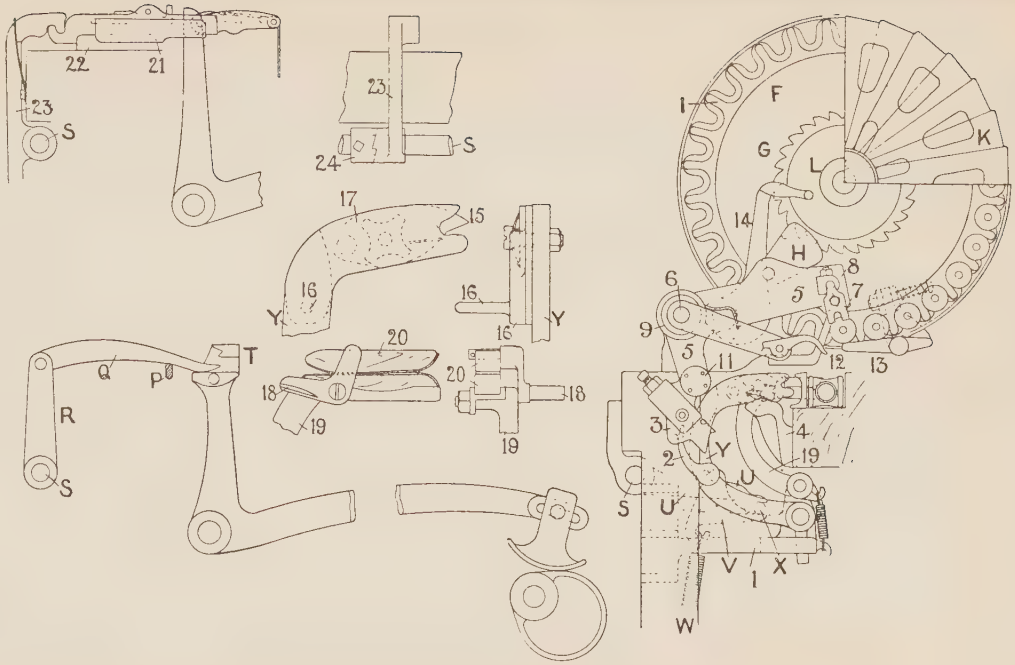
FIG. 261.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X
W

FIG. 262.

the wood, where a horn guides it to and through the shuttle eye. When once the weft is threaded the metal is shaped to prevent it from being drawn out again. Beyond the spring C a slot is cut in the shuttle face to permit a feeler to make contact with the weft, and set the change mechanism in action shortly before the supply is exhausted.

Cops or pirns when pressed upon the skewers A are placed in an intermittently rotating hopper F capable of accommodating twenty-eight skewers. F is situated over that shuttle box farthest from the driving gear. It is freely mounted upon a spindle and rotated by a ratchet wheel G and a pawl H, the latter being operated by the change mechanism. The head of each skewer A enters a semicircular recess formed in the face of a disc I, but the tips of A impinge upon recessed plates J, each being held forward by a spiral spring, as shown detached in Fig. 261. Weft is drawn from the nose of each cop over a notched disc K, and made fast at L to the hopper boss. One skewer is always immediately below the hopper axis, and, when weft fails, this skewer is forced down into the shuttle, simultaneously a spent skewer is ejected from the base of the shuttle without reducing the speed of a loom.

There are two methods of setting change mechanism in operation, namely—(*a*) by a feeler action; (*b*) by a weft fork. At the weft fork end of a slay, a feeler is mounted in sliding bearings upon the framework to face the shuttle slot. It consists of a thin brass plate M that terminates in a cylindrical shank. A spiral spring threaded upon the shank thrusts M forward, but permits it to yield to end-long pressure. A pin in M carries a cranked trip lever N, one of whose arms is furnished with an adjusting screw O, the other is free to move in a slot

in M, and rests upon a lever P. The inner arm of P is beneath a dagger Q, which is fulcrumed upon an arm R, and R is secured upon a shaft S that traverses a loom beneath the breast roller. As a slay advances to beat up, the feeler M enters the shuttle slot, impinges upon the weft, and, so long as a sufficient quantity remains, M is thrust back before the head of the screw O touches the shuttle front. As the diameter of a cop is reduced, M passes far enough through the slot to permit the shuttle to engage the head of O, tilt the levers N and P, and thus lift the free end of Q until it faces a notched bracket T, bolted upon the weft-fork hammer. As this hammer moves forward, T thrusts back the dagger Q, also the arm R, and a shaft S makes a partial revolution.

The opposite end of S controls a shuttle positioner and a weft cutter combined, by which all weft changes are effected. Thus: An arm U is screwed upon and vibrates with S. A triangular casting V is suspended from U, and a spring W is so attached to V and to the framework that its pull tends to lift the inner end of V. The inner ends of U and V being respectively above and beneath a pin X, they provide a groove for X to work in. The spring W is normally strong enough to carry a weft cutter lever Y forward, but if Y is stopped by a shuttle, the spring gives way and permits U to ascend without moving the cutter. Pin X is cast upon one arm of the cutter Y, and Y is freely mounted upon a stud Z. The lower arm of Y moves in a diagonally slotted bracket 1, shown detached in plan view, Fig. 261. When the shaft S vibrates, the pin X tilts Y towards the reed, and the slot causes Y to slide outward upon Z. The upper arm of Y serves three purposes—(*a*) it prevents a change when a shuttle is incorrectly boxed; (*b*) it effects a change when a shuttle is

suitably placed; and (*c*) it cuts the weft left between the hopper boss and the entrance to a shuttle box.

It prevents a change as follows: The lever Y slides diagonally forward and outward until the mouth of a shuttle box is reached. If, as a slay advances, a shuttle is only partially driven home, that shuttle blocks the path of Y and arrests further movement, before other parts governed by Y are brought into operation. If, when the weft fails, a shuttle is properly boxed, the head of Y crosses the race board, in a straight line, without obstruction. In doing which a bent arm 2, on the cutter lever, is moved away from a notched piece 3, fulcrumed between the prongs of a forked lever 5. A coiled spring 11 is employed to lift 3 immediately 2 is moved. Normally the arm 2 holds the notched terminal of 3 down, but as Y approaches the reed, the spring 11 lifts the notch of 3 until it faces a stop 4 upon a slay front. As the driving cranks near their front centres, stop 4 engages the notch in 3, and partially rotates the lever 5, whose centre is a stud 6 in the hopper frame. Upon one extremity of 5 a horizontal rod 7, with a notched wooden finger, is fixed above the thin end of the lowest skewer A, in the hopper F. Upon the other extremity of 5 a piece of metal 8 is situated over the head of the above-named skewer. As the lever 5 vibrates, 7 and 8 press a skewer from the hopper into a shuttle, and force an empty skewer out of a shuttle. The boss of 5 passes through a coiled spring 9; one end of 9 enters the lever and the other end enters a collar 10 fixed upon the supporting stud 6. It is the office of 9 to hold 7, 8 slightly above a skewer until the shaft S is put into action, and then to yield as 7, 8 descend.

A spring guiding finger 12 is mounted upon a stud in the hopper frame; its nose is held by a spring beneath

the thin end of the lowest skewer in the hopper. As this skewer is forced out the finger guides it into the shuttle. 12 is assisted by two other parts, namely, by a fixed plate with an inclined surface, which guides the head of a skewer; also by a lever 13, so fulcrumed upon the hopper frame that its front edge is pressed by a spring against the under side of the skewer head until that skewer is ejected from the hopper when 13 yields; it also holds the skewer in position until a weft fails. The hopper F is rotated by hinging a pawl H upon the lever 5, so that as 5 ascends the ratchet G will be advanced one tooth, and so bring the next skewer into position for use. G is prevented from receding by a holding pawl 14, centred upon a stud in the hooper frame.

The weft cutter is shown detached in Fig 262; it consists of two jaws, one made from a thin strip of steel placed in a recessed portion of the head of Y, and slightly bent forward to keep it in contact with a movable jaw 15. A cap 17 is pressed by a flat spring upon the jaw 15, and from one side of 15 a stud 16 projects. As the head of Y advances, the stud 16 engages the under surface of a wedge-shaped piece on a lever 18 which opens the jaw, but as Y crosses the race board, a casting on the slay presses against the jaw, closes it, and cuts the weft. By rotating, the hopper winds the loose ends of weft upon its boss. Another cutter is fitted in the temple, hence pieces of weft are disconnected, and a holder, situated between the two cutters, prevents these pieces from being drawn into the cloth.

An arm 19 is carried upon a stud fixed in the framing; it is held forward by a spiral spring and supports the weft holder. This holder is composed of two superposed strips of wood 20, one covered upon its upper, the other upon

its lower surface with velvet. The bottom strip is secured upon a flanged bracket by a pin, but the top strip is converted into a rocking nipper by passing a horizontal pin through a slot. This pin is in the cranked lever 18, that carries the above-mentioned wedge-shaped piece. Each time the stud 16, on the cutter jaw, passes over the wedge, the lever 18 rocks, the mouth of 20 opens to receive a thread, and a spring closes the jaw upon that thread.

It is less satisfactory to control weft changes from a weft fork than from a feeler, for a fork can only act after weft has broken or run out, and hence, broken picks, broken patterns, and thick and thin places are liable to be left in a cloth. But if a fork operates the weft-changing mechanism, whenever it engages the hammer head a loaded skewer is placed in the shuttle. The fork is mounted in a casting 21, Fig. 262, which is free to slide to and fro in a flanged holder 22. A lever 23 is loosely mounted upon the shaft S, its upper arm abuts upon 21, and its lower arm lifts a holding pawl from the ratchet wheel of the taking-up motion each time the weft fork engages the hammer. 23 has one-half of a cam-shaped clutch formed on its boss, and adjacent to this boss a collar 22, containing the complementary half of the clutch, is fixed. If 23 is moved by the weft fork, both halves of the clutch engage, the shaft S is vibrated, and the change mechanism is put into operation as usual. When changes are effected by a weft fork, the parts dispensed with are the feeler M, N, O, the lever P, the dagger Q, the arm R, and the bracket T, Fig. 261.

PART XXII

TAKING-UP MOTIONS

No exceptional mechanical difficulty had to be overcome in order to supply a power-loom with an efficient taking-up motion. The principle was introduced by M. Vaucanson in 1746, more than half a century before the power-loom became a commercial success. He pressed two rollers tightly together and drove them at a constant speed. The fabric passed partly round and between these rollers, and was by this means removed as manufactured. It is the function of a taking-up motion to draw a fabric forward regularly, and to keep a texture uniform. It should therefore contain some means for accurately fixing the position of the cloth fell, but this is usually left to the weaver. Several textile machinists now make suitable provision for this ; Messrs. Hutchinson and Hollingworth fix one wheel on the shaft of the cylinder M, Fig. 73, and another on the taking-up motion ; and pass a chain round both. If the dobby is reversed, the taking-up roller will also be reversed, hence, after unweaving, the cloth fell will be placed in its exact position for weaving.

There are two classes of taking-up motions, namely, "positive" and "negative." The former may be subdivided into : (1) Those that act intermittently, (*a*) by taking up as a slay falls back ; (*b*) by taking up as a slay moves forward ; (*c*) those in which the closeness of the weft threads is varied by changing a driving wheel ; and (*d*) those in which a driven wheel effects the change. (2) Continuous

taking-up motions. In this case the gearing requires as much time to draw one pick away as is needed to effect the cycle of movements in weaving. Of negative taking-up motions there are—*e*, those that act in conjunction with the warp tensioner; and *f*, those that act in conjunction with a loose reed.

If a positive motion implies the use of parts where nothing is left to chance the taking-up motion in most extensive use fails in two places, for the cloth passes partly round a roller whose surface is roughened after the manner of a nutmeg grater, and the roller is pushed round by a pawl and a ratchet wheel. Hence the cloth may slip upon the roller, and the pawl may slip over the teeth in the ratchet. A taking-up roller is often made of wood, its surface being covered with a thin fillet of steel which is roughened outside by punching, is wound spirally, and fastened with tacks. If a roller consists of an iron tube the fillet may be soldered on, or holes may be bored through the tube and plugged with wood, then the fillet is fastened by driving nails into the plugs. An iron roller may be grooved longitudinally and transversely to give roughness; or pins may be driven into a leather or other foundation to enable the roller to grip a fabric firmly and draw it forward. The bearings of the beam A, Fig. 263, are in the end framing, and so placed that its axis is parallel with the breast beam, the harness, and the back rest, but its periphery projects somewhat beyond the front edge of the breast beam. Although taking-up rollers are usually placed beneath a breast beam, Smith Brothers, of Heywood, more than fifty years ago raised this beam into the position of, and employed it as a substitute for, a breast beam. This plan has been adopted by the Northrop Loom Company, and a claim is advanced that a fabric will contract less in

width than when a taking-up roller is lower down in the framework.

A beam wheel B is usually set-screwed on that end of the beam shaft farthest from the driving gear; its teeth engage those of a stud pinion C, which is compounded with

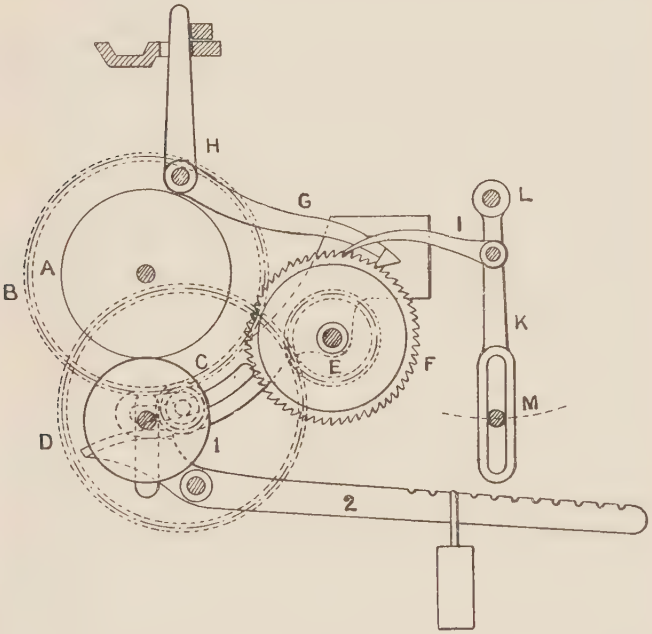

FIG. 263.

a stud wheel; both so named because they work loosely upon a stud in a slotted bracket, the slot being concentric with the beam A. Wheel D gears with a change pinion E, and E is compounded with a ratchet F. A pawl G rests freely upon the surface of F, its office being to prevent the ratchet wheel from turning backwards. A rod H extends

across the loom; upon one end the pawl G is keyed, and at its opposite extremity a finger presses against the weft-fork lever. The effect of this contrivance is to lift G above the teeth of F when a weft breaks, and thus arrest taking-up. But, as G slides over the teeth of a moving ratchet wheel F, the finger on H is vibrated. In 1903 T. Pickles and B. Blakey disconnected G and H. They mounted the former upon a stud, and provided H with a horizontal arm, then fastened a connecting rod by a pin to G, and passed it through a hole in the horizontal arm. By this plan the pawl G may slide over the teeth of F without causing H to vibrate. Also, H may be placed higher in the framework and its vertical finger may be shortened. A lever K, centred at L, has a driving pawl I pivoted upon it. A stud M is adjustably bolted to a slay sword, and passed through a slot in K; it follows that a swinging motion will be given to K, and this will cause the catch I to drive the ratchet F forward and set the train of wheels in motion. The extent of such movement in I depends upon the position of M in the slot of K.

In action this device is intermittent, for it only moves the cloth when a slay swings forward. By placing the fulcrum L beneath instead of above the driving pawl a cloth will be taken up as a slay moves backward. It has been asserted that the latter plan facilitates shedding, and tends to prevent cracks in cloth by reason of the great strain upon a warp at the time of taking-up. The pawl is the weak point; it may slip over a tooth, take two teeth, or may not be strong enough to take them regularly, hence irregularities are frequent. The heavy weighting necessary for certain goods often prevents a pawl from acting correctly. In 1880 W. Clayton employed a silent feed instead of a ratchet and pawl, and others have more recently used similar contrivances.

A wooden cloth roller 1, which should be uniform in diameter and straight, is pressed against the under side of A by weighted levers 2 that act upon the gudgeons. Both levers 2 are supported on studs in the framing and loaded at their lower ends; hence A drives 1 by surface contact and winds the cloth negatively. In place of weighted levers the gudgeons of 1 may be mounted in vertical racks which engage the teeth of two pinions. Each pinion is compounded with a pulley having a belt set-screwed upon its periphery. The belts are separately weighted and press 1 against the taking-up roller A, but 1 yields as the cloth accumulates.

A taking-up motion with a lever of the second order, as at K, must be so set that the pawl I shall drop over a tooth of the ratchet F when the cranks are on their back centres, and take one tooth at each forward movement. If more than one tooth is taken the stud M must be lowered; if less than one, it must be raised. The holding pawl G should clear a tooth by about $\frac{1}{8}''$ when the cranks are on their front centres. A lever of the second order will require less power to draw a fabric forward than one of the first order, and is therefore less liable to slip, because taking-up is effected as the cranks move from their top towards their front centres; at which time a shed is either closed or only partially open. But if a pawl acts as the cranks move from their front to their bottom centres, a shed is fully open and the strain greatest. With a lever of the first order set a pawl I to drop over a tooth when the cranks are on their front centres, and to take one tooth at each backward stroke of a slay, then fix the holding pawl G to clear a tooth about $\frac{1}{8}''$, with the cranks at their back centres. If the pawl employed is shaped to pull instead of push a ratchet round, reverse the settings given

above. Taking-up has been effected by moving one tooth at each forward and backward swing of a slay. Measuring motions are also attached to taking-up motions to stop a loom on the completion of any desired length of cloth.

Weft is placed closer in one fabric than in another, hence a taking-up roller must be made to rotate correspondingly slower or faster. This is done by changing the number of teeth in one wheel of a train, that wheel being frequently the change pinion E. The selection of suitable wheels is a simple matter, for whatever their form or position, all wheels and rollers are drivers, driven, or carriers. A driver is one that increases in velocity in proportion to its increased diameter or added teeth. A driven wheel is one that decreases in velocity in inverse proportion to its increased diameter or added teeth. A carrier merely conveys motion from one part of a machine to another without altering the value of a train; it also turns independently upon a stud or shaft.

To find the number of teeth required in any change pinion for a given number of picks per $\frac{1}{4}$ inch :—Multiply the teeth in all the driven wheels together, and divide by the teeth in the driving wheel when multiplied by the number of $\frac{1}{4}$ inches in the circumference of the taking-up roller, and by the required picks per $\frac{1}{4}$ inch. Thus, taking Fig. 263 as an example: $\frac{\text{B} \times \text{D} \times \text{F}}{\text{C} \times \text{A} \times \text{picks}}$ = the required pinion E. Assume change pinions are required to give 16 picks per $\frac{1}{4}$ inch with two trains of wheels. The first to consist of a beam wheel B of 75, a stud pinion C of 15, a stud wheel D of 120, and a ratchet F of 50 teeth respectively, and a roller A, of 15″ circumference. The second train to have a beam wheel of 75, a stud pinion of 12, a stud wheel of 100, and

a ratchet of 50 teeth respectively, and a beam 15″ in circumference.

$$\text{The first train} = \frac{75 \times 120 \times 50}{15 \times 60 \times 16} = 31{\cdot}25 \text{ teeth required.}$$

$$\text{The second train} = \frac{75 \times 100 \times 50}{12 \times 60 \times 16} = 32{\cdot}55 \text{ teeth required.}$$

Since only whole numbers can be used, the first requires 31, and the second either 32 or 33 teeth. But cloth contracts in length after it leaves a loom, and for this purpose it is usual to add $1\frac{1}{2}\%$ to the calculated number of teeth in a pinion. This is an arbitrary allowance and does not necessarily mean that all cloths contract $1\frac{1}{2}\%$. Thus $31{\cdot}25 + 1\frac{1}{2}\% =$ say 32 teeth, and $32{\cdot}55 + 1\frac{1}{2}\% =$ say 33 teeth in the wheels to be used.

Where similar trains of wheels are used for all the taking-up motions in one mill, calculations may be simplified by using a constant number, namely, the number of teeth required to give one pick per $\frac{1}{4}$″, which, divided by the picks required per $\frac{1}{4}$″, will give the number of teeth for a change pinion.

$$\text{The constant for the first train} = \frac{75 \times 120 \times 50}{15 \times 60} + 1\tfrac{1}{2}\% = 507.$$

$$\text{The constant for the second train} = \frac{75 \times 100 \times 50}{12 \times 60} + 1\tfrac{1}{2}\% = 528.$$

Then a pinion for 16 picks per $\frac{1}{4}$″ with the first train must have :—

$$\frac{507}{16} = 32 \text{ teeth.}$$

$$\text{One with the second train} = \frac{528}{16} = 33 \text{ teeth.}$$

Inverse proportion may also be used to find the number of teeth in a pinion; thus if a 33 pinion gives 16 picks, what wheel will give 20 picks? 20 : 16 : : 33 : 26, the teeth required. Changing a driving wheel involves the trouble

of making a calculation, and the risk of employing a wrong wheel. To reduce this risk, tables of change wheels are compiled for easy reference.

Many variations from the above-described motion are to be met with. An alteration of one tooth in a pinion may make too great a change in a fabric, for in some heavily picked goods one tooth equals two or more picks per $\frac{1}{4}$ inch. In such cases a train of seven instead of five wheels is employed. A driven wheel is sometimes changed instead of a driver; when this is done calculations may be rendered unnecessary, for the wheels forming a train may be such that the number of teeth in a change wheel equals the number of picks per unit of length in a fabric. Thus, in Pickle's motion the ratchet has 24, the first pinion 36 (the first stud wheel is the change wheel), the second pinion has 24, the second stud wheel 89, the third pinion 15, and the beam wheel 90 teeth respectively; the cloth roller has a circumference of 15·05″

$$\therefore \frac{24 \times x \times 89 \times 90}{1 \times 36 \times 24 \times 15 \times 15{\cdot}05} = \frac{89}{90{\cdot}3}, \text{ but } 89 + 1\tfrac{1}{2}\% = 90{\cdot}3 \therefore$$

the teeth in the change wheel equals the picks per inch. If the wheel of 36 teeth is replaced by one of 27 teeth, a change wheel equals the picks per $\frac{3}{4}$ inch; if by 18 teeth, a change wheel equals the picks per $\frac{1}{2}$ inch; and if by 9 teeth, a change wheel equals the picks per $\frac{1}{4}$ inch; the latter number is, however, too small for practical purposes. The number of teeth being clearly stamped upon each change wheel, mistakes are not of frequent occurrence (see also Keighley's positive take-up motions, p. 513).

The chief difference between intermittent and continuous motions is found in the manner of driving. In the latter a side shaft A, Figs. 264 and 265, is fixed at right angles to,

and is driven from, the picking shaft B; it gives motion to a fabric by means of two bevels C, D, a worm E, a worm wheel, F, a change pinion G, a stud wheel H, a stud pinion K, a beam wheel L, and a beam M. The velocity of M depends upon the dimensions of the wheels and roller employed to drive it. The worm E has been mounted loosely upon A, and its boss made in two parts to form a clutch, one part being fast upon A, the other connected to the weft fork finger. When the finger acts the clutch is opened and taking-up

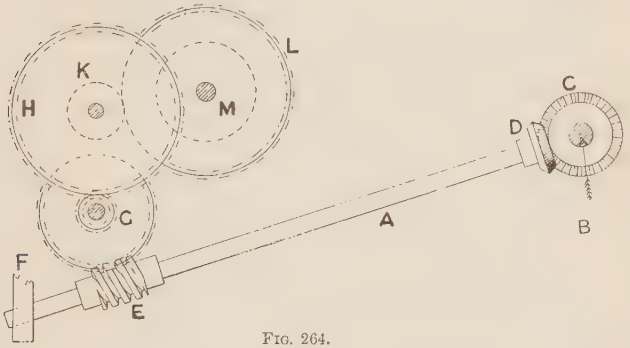

FIG. 264.

is arrested. This device is positive in action, for if M is covered with card clothing, or with pins, slipping is impossible. It also possesses the further advantage that if a loom is turned backward the cloth is also moved back. In intermittent motions, on the contrary, a pawl acts in the same manner, irrespective of the direction of movement in other parts of a loom. Hence cloth may be drawn forward when weft is absent, and unless a weaver lets back the fabric before recommencing to weave, cracks will be produced.

Cracks and thick places are therefore avoided by the weaver's skill to judge correctly the distance to reverse

a cloth after unweaving, and after weft has broken. So-called crack preventers are frequently attached to taking-up motions ; they let back a predetermined number of picks each time a loom is stopped by a weft fork. But since weft may break one to one and a half picks before a weft fork acts, these contrivances will either permit cracks to be made, or when a fork acts immediately

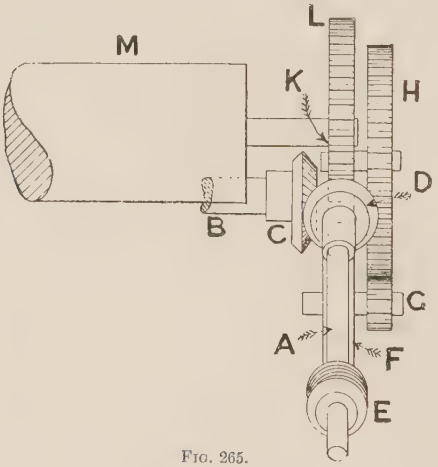

FIG. 265.

a weft breaks, they will make thick places. Such an attachment consists of two holding catches, one of which is free to slide through a space equal to two or more picks. If a weft breaks, the taking-up and the ordinary holding catches are lifted, but the sliding catch remains in contact with the ratchet and yields to the predetermined extent.

In bordered and cross-striped fabrics it is often necessary to place weft threads closer together in one portion than in another. This may be done by causing the shedding

motion to effect the change. Thus: A cord from a spare jack in a dobby is tied to one end of a spiral spring, and another cord from the opposite end of that spring is tied to a light lever secured upon the rod H, Fig 263. A spring is employed because the oscillation of H is limited by the length of slot in which its finger is placed, hence, once the finger has completed its journey, any additional movement in the jack will merely stretch the spring. When the rod H is vibrated it must carry the holding pawl G out of gear with the ratchet F, without disturbing I, and further taking-up will cease until the shedding motion permits G to fall. By lifting G on alternate picks the cloth will be drawn forward at half the speed; this is equal to doubling the number of weft threads per inch. Other proportions may be obtained by giving the pawl varying periods of inactivity, as, for example, if it is lifted twice and allowed to remain down once, the number of picks will be trebled. Or, if lifted once and left down twice, the number of picks will be increased by $\frac{1}{3}$.

Negative, or drag motions are employed for fabrics that would be injured by a roughened roller, also in cases where the weft is so irregular in thickness that a fabric, if drawn away positively, would be full of uneven places. In most negative motions change wheels are unnecessary, for in beating up, the reed slackens a fabric, and a weighted lever, a pawl, and a ratchet wind the cloth upon a smooth roller. By using such a roller the picks are not liable to be pulled out of their appointed places. Close attention must be given to the relative weighting of the warp beam and the taking-up lever, or the decreasing diameter of the warp beam and the increasing diameter of the cloth roller will cause a fabric to be drawn away irregularly. Negative motions are readily adjusted for

heavy fabrics, but light ones give more trouble. In heavily weighted warps the thickness of the weft controls the taking-up, and a uniform bulk of cloth may be produced without the necessity for letting back when a weft breaks, but in lightly weighted goods it is possible to take up for a few picks after a weft has broken.

As applied to fustian and velvet looms, the parts consist of a cloth roller A, Figs. 266 and 267, with a worm wheel B fixed upon it. A worm D on a short shaft C gears with B, and two ratchet wheels E, F are provided with compounded holding catches. At E there are two and at F three catches, all slightly differing in length. The shaft C serves as a fulcrum for a slotted lever G, that carries the pulling catch H, and also a loosely jointed pendent stalk K. Near the base of K a fixed collar rests upon a slotted arm L, projecting from a slay sword M. The lower portion of K passes through L, and its collar permits of the stalk being loaded with adjustable weights N; these enable the catch H to pull the ratchet E forward. When a loom is active the slay's vibrations are transferred to the arm L, and as L lifts the stalk and the lever K, G, the catch H engages a tooth of the ratchet E. The parts G, K, and N are then suspended from E until weft accumulates sufficiently to cause a reed to slacken a fabric, and the weights N to move the ratchet E. The holding catches on E, F prevent backward movement. To increase the number of picks per inch the weights on the warp beam must be increased relatively to those at N, and to reduce the picks both sets of weights must be brought nearer to a state of equilibrium. In either case the exact alteration is made by trial. The weights upon the warp beams are adjusted once or twice daily; those at N are seldom disturbed except when a considerable alteration is made in the build of a texture.

On silk looms a taking-up motion is usually controlled by a loose reed that swivels upon two pins in the ends

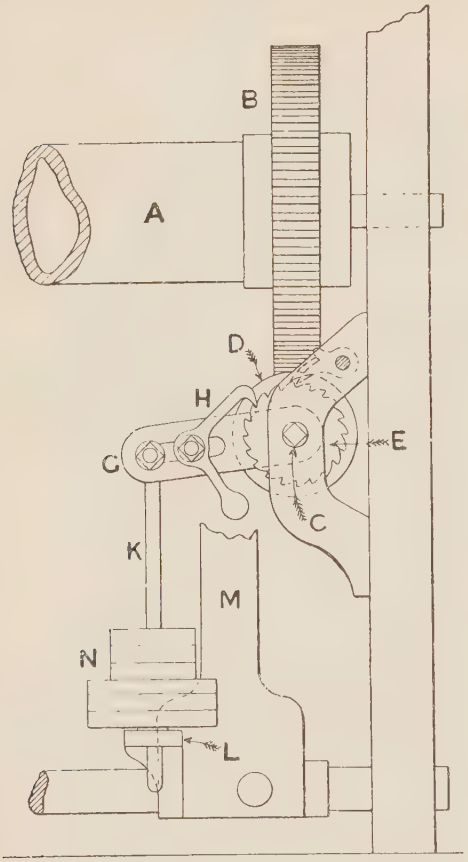

FIG. 266.

of a slay cap. This plan was patented in 1836 by C. G. Gilroy. The reed is normally kept vertical by causing

a spring C, Fig. 268, to press one arm of a lever D against a case B. The lever D is fulcrumed at E, and furnished at F with an adjusting T-shaped piece. All the

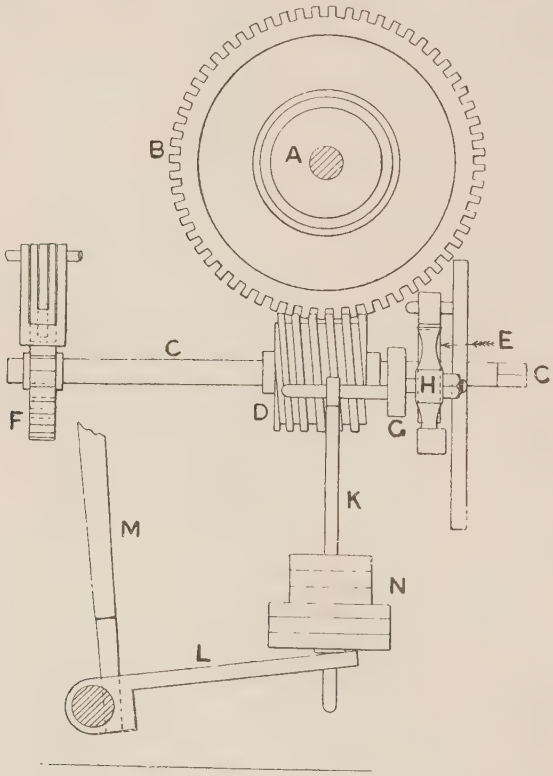

FIG. 267.

above-named parts are attached to and swing with the slay.

Immediately in front of F a lever is centred upon a pin at G′, and connected at G with a pawl H, which rests upon

a ratchet wheel 1. This ratchet is compounded with a spur-wheel 2, and 2 drives a pair of compounded wheels 3, 4; the last-named gears with a beam wheel 5, fixed

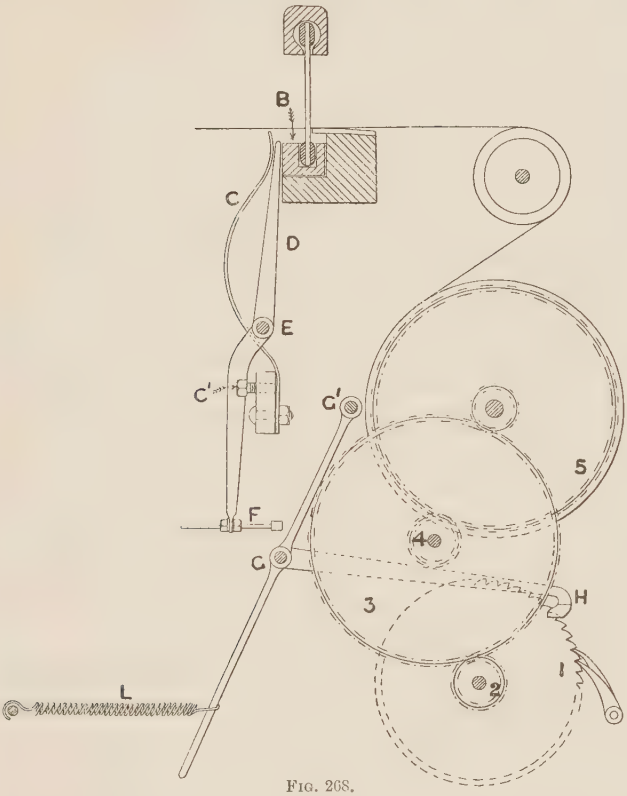

FIG. 268.

upon the shaft of a taking-up roller whose circumference is one yard. Cloth is only drawn forward when the reed is pushed back by the weft. At such times the head F thrusts the catch H forward; in doing this a helical spring L

is stretched, but as F moves back the spring contracts, and sets the train of wheels in motion. To increase the number of picks the spring C must be tightened, and to reduce them C must be slackened by means of the adjusting screw C′. Greater alterations may be made by changing a wheel in the train.

J. Honegger applies a taking-up motion to silk looms which is capable of finer adjustment than Gilroy's. It is shown in Fig. 269, where the reed A is held in an upper and lower case B. Both cases are mounted in arms C, and upon a shaft D. The bearings of D are on the slay sword S, and D has two other arms E that terminate in anti-friction bowls F. As a slay swings back the reed is kept steady by reason of these bowls making contact with two bow springs G. Normally the reed pressure is regulated by hooking two spiral springs H into the arms of E, passing their ends through castings I on the swords, and providing them with thumb-screws J.

A pin K projects from the slay and impinges against the lower reed case B; it is kept forward by a collar and a light, open-coiled spiral spring. Facing K is an adjusting head on a lever L, whose fulcrum is at M. The lower arm of L has a pin from a latch N resting upon it, and so long as the reed is not pressed back by the weft, K thrusts back L and lifts N above a catch in a bar O to prevent taking-up. Should beating-up become difficult the reed falls back, the latch N remains unlifted, and taking-up proceeds. The bar O is connected by a lever P, having a fulcrum at Q and a link at R to a slay sword S. Adjacent to O a slotted slide bar T is supported by studs, and carries the latch N. When N engages the catch in O the bar T is pushed forward and takes with it a bar U, whose rear end is pinned upon a slotted lever V, and V swings upon a stud

W. This lever is made to rock a second slotted lever X upon its centre Y. Thus: a block 1, placed in the slot

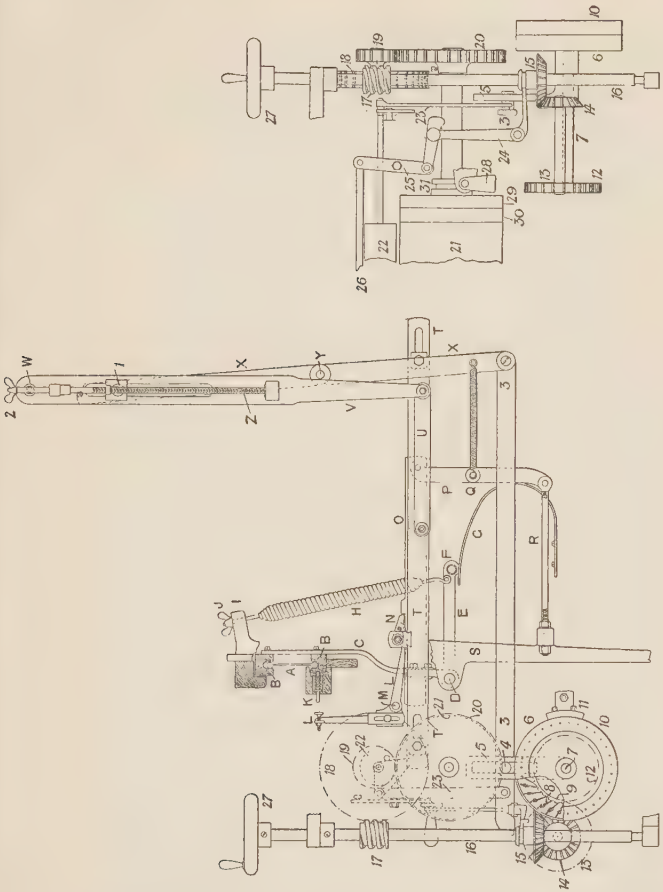

FIG. 269.

of V, unites V, X by a pin. A screw Z, having its bearings in V, passes through a nut in 1. By turning a thumb-screw

2, the block 1 will either rise or fall, and V, X will be united in different places. Since V swings through the action of N, O, T, U, the lever X imparts motion to a bar 3, but the extent of that motion depends entirely upon the position of the pin in the slots of V, X. At 4 a stud from the bar 3 passes through a slotted arm 5. The last named is fast upon the boss of a flanged disc 6, while 6 is loose upon a shaft 7. Inside the flange of 6 are thirty-one drivings pawls 8, all thrust forward by flat springs against the teeth of a broad ratchet wheel 9, having thirty teeth, and being fast upon 7. A second flanged disc 10 is bolted to the framework at 11; it carries a similar number of pawls to the disc 6; they also bear upon the teeth of 9, but merely to prevent backward movement. The flanges on 6, 10 enclose the ratchet wheel. On the inner end of the shaft 7 a spur wheel 12 is fixed to drive a wheel 13, and 13 is compounded with a bevel 14 in order to drive a second bevel 15 upon an upright shaft 16. At 17 a worm on the upright shaft engages a worm wheel 18; the latter being compounded with a wheel 19 to drive the wheel 20 and the taking-up roller 21.

The fabric passes over a breast beam, behind a roller, thence in front of a second roller 22, and to the cloth roller 21. As a piece of cloth accumulates upon 21, the roller 22 is pushed up by the cloth. In rising, 22 takes with it a bar 23, which is also fast upon 3; this lifts the pin 4, in the slot of 5, thereby reducing the movement of the taking-up roller. A clutch is formed on the boss of the wheel 15 and operated from the starting handle through the levers 24, 25 and a bar 26; so that on putting a loom in motion the clutch closes; on stopping it the clutch opens; to dislocate the taking-up and permit adjustments to be made by the hand wheel 27. A disc 29 is fast upon the

shaft of 21. From the inner face of a sliding boss 31 a pin normally passes through 29 into a hole in a metal hoop 30, on one end of 21. A ring groove in 31 receives a pin from an eccentrically mounted piece 28. By turning up 28, the pin of 31 is withdrawn from and loosens the cloth roller 21; a fabric may then be removed from the roller without interfering with other parts of the taking-up motion.

PART XXIII

TEMPLES

During weaving, cloth contracts in width by reason of the tension upon both warp and weft. As the warp threads separate to form top and bottom sheds they simultaneously close upon the last thread of weft, and exert sufficient force to produce a series of corrugations along its surface. If a bent thread is required to cover a given width of cloth, it must be longer than a straight one; but, since extra length cannot be provided, the cloth becomes narrower. Temples are employed to counteract contraction, and thus prevent the edge threads from being broken by the reed, and the reed from being injured by the warp.

Self-acting temples date from 1786, when Dr. Cartwright patented the application of nippers that opened as a reed advanced and closed upon the cloth as a reed retreated from the fell. At a later period cog wheels, rings, and rollers were tried, but with small advantage to inventor or manufacturer. It was not until 1839, when J. Smith

patented the "penny temple," that success was achieved. Even then self-acting temples were not in great demand, for so late as 1870 many fabrics were woven by the aid of wooden temples which were moved manually. At the present time, however, self acting temples are in general use, and are of varied types. They include the trough and roller; single, double, and three-roller side temples; inclined and horizontal rings, nipper, and other styles.

The trough and roller temple was patented by W. Kenworthy and J. Bullough in 1841, and has been extensively used for light and medium fabrics. It consists of a semicircular iron trough A, Fig. 270, that extends across the reed space. It is placed beneath a fabric with the hollow part upwards, and the ends are recessed to form bearings for a case-hardened roller B whose diameter is $1\frac{1}{8}''$ to $1\frac{1}{4}''$. Two caps C pass over the journals of B and are secured to the holder by bolts. The roller is fluted for 12″ to 18″ from each end, but a plain portion, from 4″ upwards, is left at the centre. The flutes on one side of the plain piece have a left-handed thread chased amongst them to form sharp teeth, and a right-handed thread is chased amongst those at the other side. The whole is supported upon two long spring-stands D which are bolted to the front rail of the loom. In case a shuttle is trapped in the warp, the springs give way and the temple rolls back without doing damage. If at such times the reed is a loose one the trough also assists in forcing back the reed. In fixing this temple in position the front edge of the trough is moved as near the cloth fell as possible without touching the reed, and the roller should turn freely in the trough. As a fabric passes over the edge of A it is deflected by the roller B, and the maximum bite is obtained by raising the front of A until a fabric forms a sharp angle. This temple

is not adapted for heavy work, and is seldom used for cloth more than 60″ wide. Its ability to prevent contraction is not great, for a cloth is only held by frictional contact

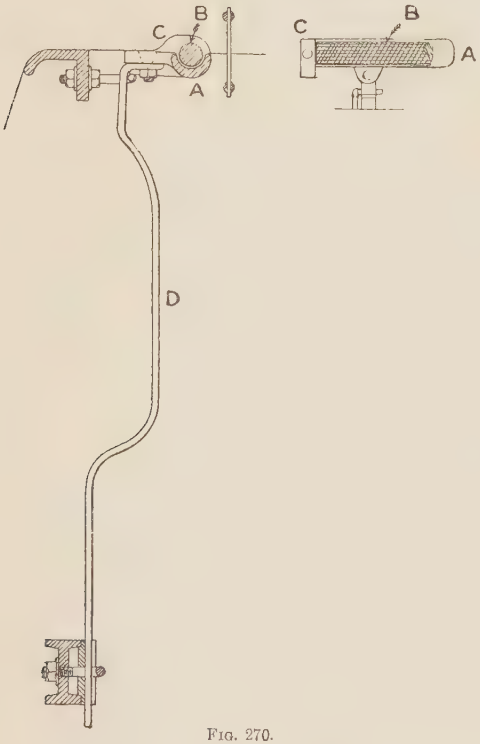

Fig. 270.

with B; and the roller wears comparatively smooth. It cannot distend a fabric; still, by making the outer ends of a roller conical for about 12″, the selvages will be firmly held. If a cloth does not approximate to the reed space, the thick ends of a conical roller will not permit its centre

to be pushed far enough forward. This temple covers about 2″ of the newly woven piece, and thus prevents the ready detection of defects; the race board must also be lower than is necessary for most temples, but a claim is made that it gives a better cover to cloth than side temples. Should any hard substance be accidentally interwoven, the cloth will be torn by the trough.

Side-Roller Temples

Single-roller side temples were patented in 1824 by J. C. Daniell. They are specially adapted to hold out light fabrics: but are also fitted on medium and moderately heavy looms, in which the slay moves too near the breast beam to leave room for more than one roller. They are fitted in a cast-iron case, and mounted at each side of a fabric upon a rod A, Fig. 271. The rod may be provided with holes for two studs B to pass through, in which event B, B are bolted on the breast beam; each has a spiral spring pushed over it to hold the temple forward, and a nut C to secure A upon B. Or flat S-shaped springs may take the place of spiral springs. Where space is of less importance, a flat rod is often fastened to long springs similar to those shown at D, Fig. 270.

For light goods the rollers D are box-wood, with steel journals, and steel hooped at one end. But solid brass and steel and brass shirted rollers are often used. In each case finely pointed steel pins are driven into the rollers spirally. Soft steel, from 3″ to 6″ long by $\frac{1}{2}$″ in diameter, is also employed. The body of each roller then contains a large number of short, sharp points which lean towards the edges of a cloth. Some rollers are slightly conical in form, the taper being from $\frac{3}{4}$″ to $\frac{5}{8}$″ in

diameter on a 4″ roller. A temple case is open below to allow size and dirt to fall out. A movable cap is screwed down tight, but a space is left facing the roller axis for a fabric to enter; as the latter is drawn forward, it is bent over the roller points and held by them with sufficient tenacity to ensure good weaving and still leave the piece fairly free from marks.

Many temples are capable of preventing a fabric from contracting unduly, but are unable to distend it. Since cloth contracts between a reed and the bite of a temple, it is often desirable to stretch it slightly while in contact

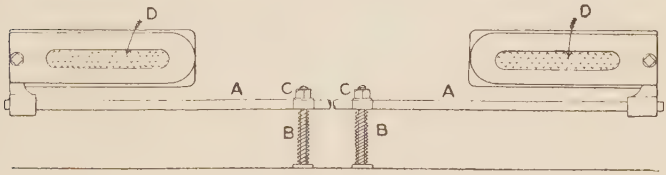

FIG. 271.

with the temples. One of several similarly constructed single-roller temples was introduced by William Lancaster; it has a fixed spindle D, Fig. 272, for a boss A to turn upon. A is $1\frac{3}{16}$″ in diameter, and has fourteen longitudinal grooves cut in its periphery at equal distances apart. A set of saws B, with fine teeth and smooth protruding ends, fit loosely into the grooves of A. At each end of the spindle D a hollow collar C, with an inclined edge, is secured, and all the smooth projections on the saws B enter the recesses of C, C and are thus prevented from falling out of A. As the boss A rotates, one end of each saw bears in succession against the cam-shaped edge of the inside collar and slides outward. This teeth of B carry the cloth out with them at both sides simultaneously. This temple is

liable to become choked with dirt and loose threads. Another modification contains four toothed segments that enclose a boss in which a cam groove is cut for a pin from each of the segments to enter. As the boss revolves, the pins are pushed outward quickly but return slowly.

Most roller temples have greater holding power than a trough and roller, because the rollers are often fitted with

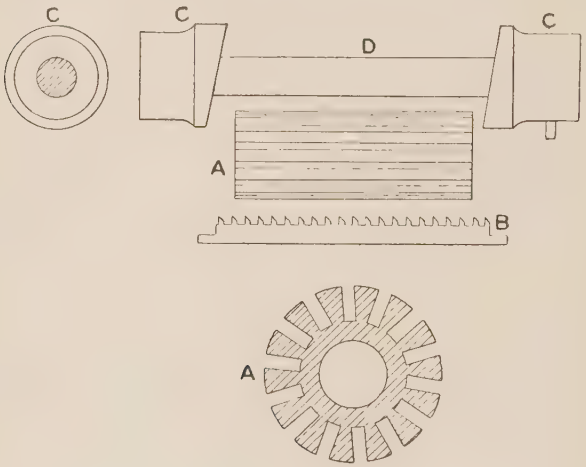

Fig. 272.

pins that pierce the cloth. They are made in different ways. In the coloured section of the cotton weaving industry double-roller temples are largely used, the rollers being from $3\frac{1}{4}''$ to $6''$ long, and from $\frac{7}{16}''$ to $\frac{11}{16}''$ in diameter; and they are placed in pairs near each edge of a fabric. Both may be of uniform thickness; or they may be conical, with a slope of from $\frac{1}{16}''$ to $\frac{1}{8}''$ on $4''$ of length. In the latter case the thick edges bear upon the selvages and hold the cloth tightest where contraction is most

harmful. The rollers may be held parallel, or they may converge towards the centre of the fabric. On the outside the centres may be $1\frac{5}{16}''$ apart, and on the inside $1\frac{3}{16}''$ to $1\frac{4}{16}''$ apart. Both may be similar in material and in the shape of tooth, or one may be wood or brass, the other iron, and their teeth may be formed and inserted differently.

A cast-iron or other metal case is provided with bearings for the roller pivots and fitted upon brackets secured to the breast beam. A case should allow the pins of the front roller to be brought within $\frac{1}{8}''$ of the face. Thin steel appears to be best adapted for this purpose, and it should be set as near as possible to the reed without touching. Its slope should coincide with the warp line between the breast beam and the harness eye when a shed is closed, and it should be placed as low down as possible without touching the slay. Adjusting pieces are provided for the inner pivots to prevent longitudinal movement in the rollers. The fixings must provide a means for lateral adjustment, also for moving the temples forward or backward. Spiral springs, short horizontal, and long vertical flat springs are used to hold the temples forward, and to permit them to move backward when a shuttle strikes them. Of these, long vertical springs are less liable to become stiff and spoil a reed than either of the others. The cap may be brass, cast-iron, or steel; its front and back edges, together with a longitudinal central rib, divide the cab into two semicircles and press the cloth down level with the axes of the rollers. If an angle bar is attached to the front edge of each temple case, and crosses a fabric close to the fell, it not only prevents the shedding harness from lifting that fabric, but it assists to throw out a loose reed when a shuttle is trapped. If properly constructed, this temple is as simple and effective as any available,

and is applicable to a very wide range of fabrics. The cap is, however, liable to glaze dark, uniformly coloured cloths.

Three-roller temples have been introduced in order to remove this defect. They may have two outer rollers in a case, and the centre one in a cap to take the place of the middle deflecting piece. Or two rollers may be fixed in a cap, and one in a case, which is equal to using the former upside down. The teeth should be as short as possible or they will not liberate the cloth without marking it.

Ring Temples

Inclined rings or segment temples were invented in Switzerland by M. Mathis, and introduced into this country about 1870. They are almost as varied as side rollers. From a single ring, with two or three lines of pins, to upwards of twenty rings, each with one row of pins, are met with. Some are made with two rings placed one behind the other on separate studs $1\frac{1}{8}''$ apart, and covered with a double semicircular cap. But the most general form of this temple consists of a series of parallel brass rings A, Fig. 273, which are $\frac{3}{16}''$ broad by $\frac{7}{8}''$ in diameter, and furnished with a single line of fine radiating steel points. Washers B hold the rings $\frac{3}{16}''$ apart. They are flat on one side, but an eccentric boss is formed on the other side, whose length equals the width of a ring, and every washer has a hole drilled obliquely through it. A stud C, about $\frac{3}{8}''$ in diameter, is securely fixed in an inner end-piece, and the rings and washers are placed upon C with the full side of each eccentric uppermost. When all are in position a second end-piece E is slipped upon C and the whole bolted into the temple-holder F. The obliquely

drilled holes in the washers hold the rings A more or less diagonally to the axis of C, and the eccentrics carry the pins above the upper surface of B and inside their lower surfaces.

For rollers $1\frac{5}{16}''$ in diameter, the rings A are often $\frac{1}{4}''$ apart and slope towards the selvages at an angle approxi-

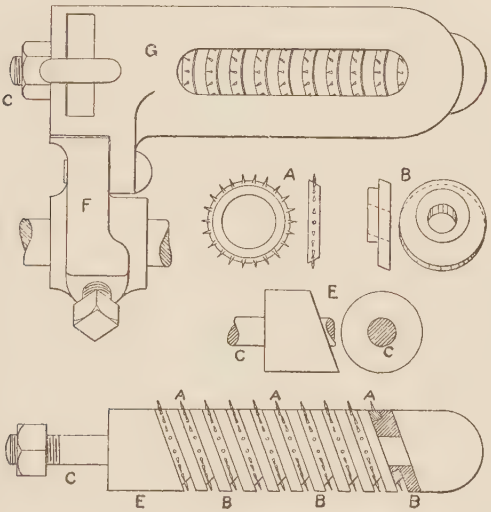

FIG. 273.

mating to 22° from the vertical. Broad looms, however, are provided with temples that vary from 6″ to 9″ in length, and contain 15 to 20 rings. In long temples the rings are seldom equidistant, nor is the angle of inclination a fixed one. A 17-ring temple, for example, may be $1\frac{1}{16}''$ in diameter, and the two outside rings $\frac{5}{16}''$ apart, while the two inside ones are $\frac{3}{4}''$ apart. As they approach a selvage, the inclination of each increases, but the parts

cease to be interchangeable. To prevent these temples from becoming choked with dirt and size a notch has been cut in the bottom of each washer B, then as the rings rotate they scrape against two sharp edges and cleanse themselves. Another plan is to form a ring with a flange that overlaps the edge of B, for the purpose of preventing dirt or threads from getting between A and B.

Ring temples stretch a fabric to about the reed width and are applicable to wide and narrow looms. Those with a single ring act on the selvage only, and are mostly used for fabrics that would be injured by temple marks showing in the body, such as dress goods, velveteens, and light fustians. Provision is made in single ring temples used on velveteen looms for temporarily moving the temple inward in the event of the cloth becoming detached from the temple, so that the cloth may be replaced, and then the temple is put back to its normal position. Stout calicoes of medium width require from six to ten rings, while heavy sheetings have from twelve to fifteen rings. This temple is liable to injure the edges of delicate fabrics, and if a ring becomes clogged it tears the cloth.

Horizontal ring temples were invented in 1839 by J. Smith, and are the oldest now in use. They consist in bolting upon the inside of a breast beam a slotted bracket A, Fig. 274. In the slot of A a thin plate B with two overlapping edges is secured, and B has a flat spring riveted at its centre. A thumb-screw C traverses A and passes through a tongue in B. By turning C to the right or left, a temple can be adjusted laterally. A plate D is pushed between the overlapping edges of B and above its flat spring, so that the combined pressure of the spring and the bent edges may hold D tight. A brass roller E, $1\frac{3}{8}''$ in diameter, has three lines of radiating steel pins all $\frac{1}{8}''$ long.

E is laid horizontally upon the holder D and a screw is passed freely through its centre; it is encircled by an oblique rim F, in which a diagonal slit G is cut for the edge of a fabric to enter, and by which it is bent over the pins H. A wider slit at the rear permits a fabric to leave the temple. In action a selvage is gripped by the

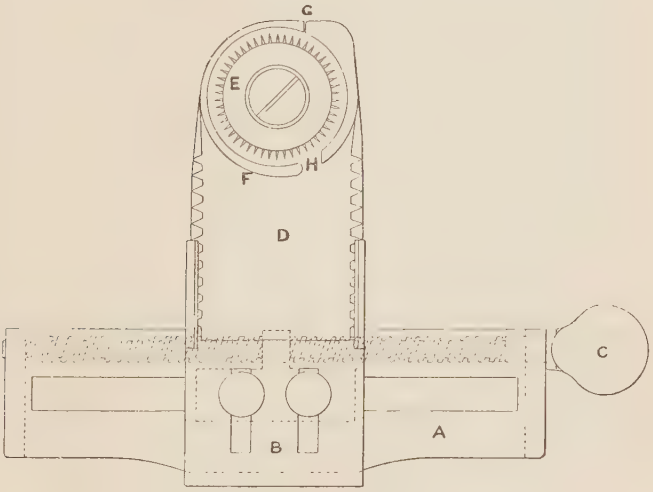

FIG. 274.

pins and stretched from the point of contact round the outer extremity of E; but, after passing that point, a fabric contracts again until it passes out by the wide slit.

In case a shuttle is trapped, the plate D is forcibly driven back and requires to be adjusted manually before restarting a loom. This temple holds a cloth firmly, but is troublesome to manipulate after unweaving, as the holder is not sufficiently flexible. It is also dangerous to use, for

if loose weft is broken off while a loom is in motion, there is a risk of crushing a weaver's fingers.

Other things being equal, the best temple is that which will grip and stretch a cloth nearest to the fell; stretching a piece half an inch or more from that point is less efficient. The Dutcher temple enables cloth to be stretched nearer the fell than most others. Its case has a shank cast upon it which is partly oblong, partly cylindrical. The cylindrical portion carries an open coiled spiral spring, so that one end impinges upon the oblong shoulder, the other upon the end of a slotted box in which the shank is placed; the box being adjustably secured upon the breast beam. A heel, cast upon the under side of the temple case, is engaged by an advancing slay and the temple is pressed back. As a slay recedes from the fell the spring pushes the temple forward. By this means a temple case can be set in advance of the fell without risk of injury to the reed. In practice it has been found that thin goods are marked by temple teeth and stout goods are not properly held. In this roller the teeth are longest near the outer end and taper down to the inner end. For fine goods they are uniformly distributed over the roller, as then they do not pierce a cloth, but release it freely. For stout cloth half the pins are removed from six outside rows in order that those remaining may more readily pierce a cloth, and hold it longer. The roller is $2\frac{1}{2}''$ long by $\frac{9}{16}''$ diameter, and bored axially to receive and turn freely upon stud journals. Each stud has a thread cut near its head, but the smooth portions enter the roller. The cap is tapped at each end to receive the studs, and in order to make one bearing dust-proof, the inner end of a roller is turned down to fit inside a recessed cap.

PART XXIV

INTERNAL AND EXTERNAL SELVAGES

When two or more pieces are woven side by side in a loom and subsequently cut asunder, internal selvages hold the inner edge threads in position. Such selvages are inferior to true ones, but are serviceable where strength is of minor importance. Adjacent threads of the inner edges may be twisted half or wholly round stationary threads, or twisting threads may cross other threads that work in plain order. The simplest apparatus consists of a doup of worsted heald twine, which terminates in a pendent ring. This doup is tied to the front shaft; the crossing thread is passed through an eye in a back shaft, it is next bent under one or more straight threads, drawn through the pendent ring, and with the straight threads passes into one dent of a reed. The crossed thread is lifted each pick; first by a back shaft to form an open shed, and next by the doup to form a crossed shed. From two to four dents are left empty between each pair of selvages according to the fineness of a reed. The objections to the above plan are, that the crossing threads cannot be lifted by a doup more than half the depth of a shed, that a doup chafes as it is pulled round the stationary threads, and breaks frequently. Fabrics may be split while in a loom by drawing the gaps over fixed knives, but they are usually cut after leaving a loom.

In 1889, Briggs Bury introduced a pair of flexible chains with a small ring at each end. By means of heald twine he attaches the upper rings to the back and front shafts

respectively. The chains hang free at their lower ends, and the crossing threads are drawn through both pendent rings. When the front shaft is raised, a cross shed is formed and the chain on the back shaft hangs in a loose loop. Also, when the back shaft is raised the same edge thread is lifted in an open shed, but the chain on the front shaft loops round the other side of the stationary thread. When both shafts are level, both chains hang slack and form loops below the warp. By their superior strength chains resist friction for a much longer period than twine, and their flexibility, cheapness, and weight well adapt them for the purpose.

In 1886, J. W. Shorrock and T. B. Taylor patented the split motion shown in front and side elevations in Figs. 275 and 276. It consists in bolting a framing A to a cross rail above the warp. From A a wire B descends below the bottom shed line, and is there coiled to form two eyes C that take the crossing threads 1 for adjacent selvages. At D two small flanged rollers turn freely upon studs in A. Two straps E, E are bent round D, led through guides F, and, on plain looms, one end of each is made fast to the periphery of a pulley G, set-screwed upon the heald-roller shaft H. A piece of elastic 1 is hooked into the bend of wire support J, and the opposite ends of E, E are secured to it. At L two brass eyelets are fixed in E to take the crossing threads 1, and the stationary threads 2 are drawn through separate eyes K in the frame A.

The oscillating motion of H causes G alternately to unwind the straps from, and wind them upon, its surface. As they unwind, the elastic I draws E up, and the eyelets L carry the crossing threads 1 beneath the flanged rollers D, and up on one side of the stationary threads 2. The reverse vibration of H moves all the parts back to their

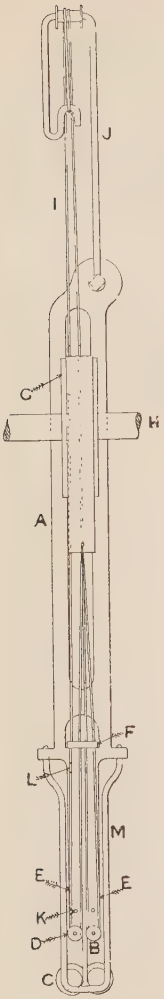

Fig. 275.

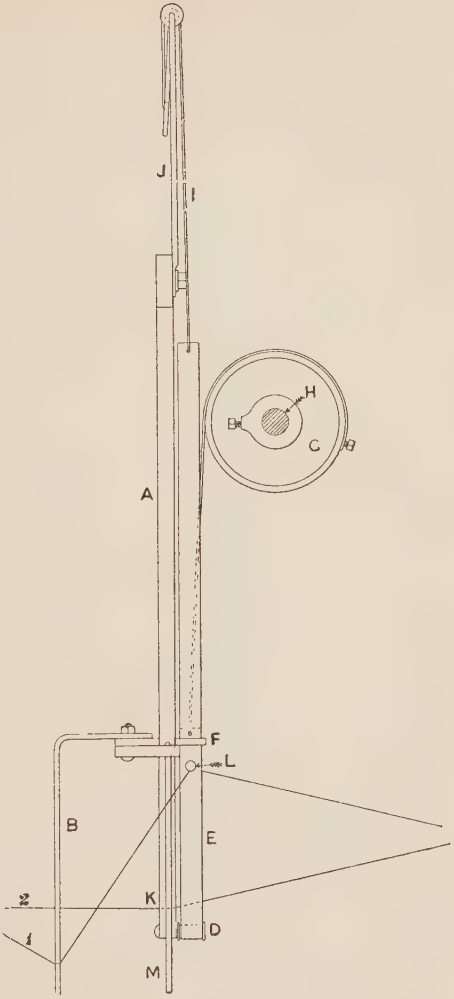

Fig ,276.

initial positions, and places the threads 1 on the opposite sides of 2. The wires M merely hold the ordinary warp threads away from the moving straps E. This split motion is comparatively inexpensive, and may be controlled by tappets, dobbies, or Jacquards. In case either of the last named is used, a jack of one and a harness thread of the other are connected to a light lever that multiplies the lift of the straps E, for E must move through approximately twice as much space as either healds or harness.

A motion of French construction differs from Shorrock and Taylor's; chiefly in causing the threads that do not cross to weave in plain order instead of remaining stationary. The mechanism serves two functions, namely, to weave gauze and to weave plain.

Figs. 277 and 278 are respectively front and side elevations. Three compounded pulleys A, B, C are suspended from a loom rail; D, D′ is a strap which is screwed upon A; its ends are connected to two treadles that are moved alternately by cams to vibrate the pulleys A, B, C. Or a spring may be attached to D, or D′, in which case one treadle and cam will serve the purpose. The thick line E is an endless piece formed partly of strapping, partly of twine, and is fixed to the surface of C. It carries two mails F—one for each selvage, and is led round grooved pulleys G, H, G′. If A, B, C turn in either direction, both mails F, and the warp threads they contain, will pass under the pulleys G, G′, and ascend on the other side. In doing this, each mail carries its warp round two threads that are drawn into the same dent as a crossing thread. The plain threads are moved by a third strap secured to a pulley B. Opposite ends of this strap are attached to cords I, I′. The cord I is bent round a pulley K, from whence it passes diagonally up to, and is tied upon the cord I′, and I′ is

taken round a pulley K′ and up to I. Each cord carries

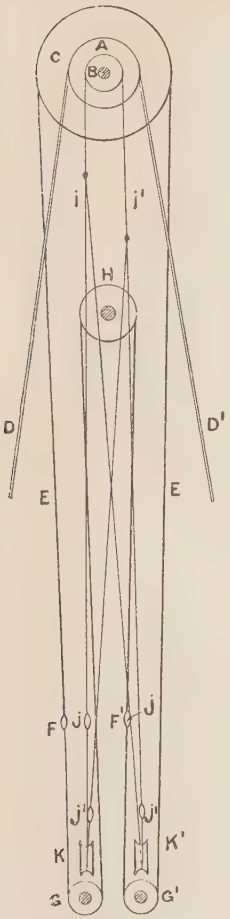

FIG. 277.

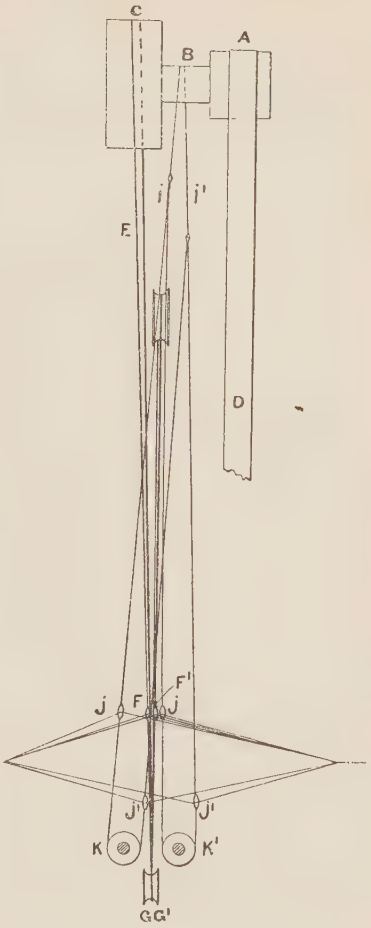

FIG. 278.

two mails J, J′ that operate parts of separate selvages.

Hence if an oscillation of B causes the mails J, J to ascend, J′, J′ will descend, and the motion of B when reversed will lift J′, J′ and sink J, J. Taking both actions together, the cords appear to be complex, but if a moving thread merely twisted half round a stationary one, the device would be as simple as that invented by Shorrock and Taylor.

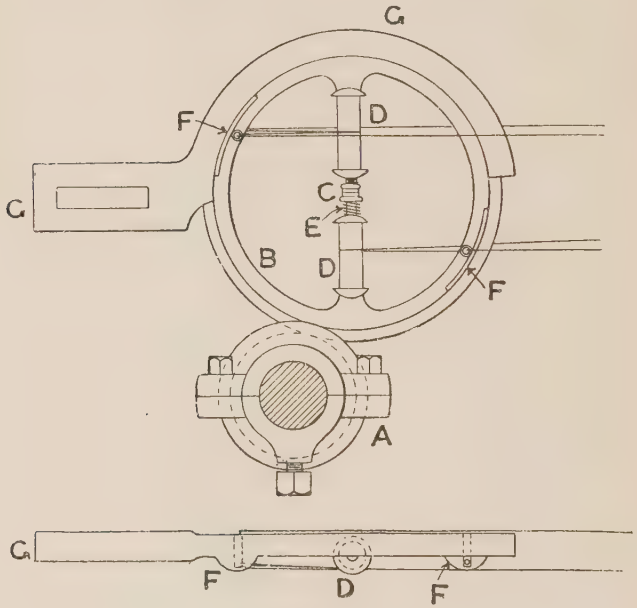

FIG. 279.

Two pairs of needles have been fitted in frames: one pair to point downward and move in a vertical plane; the other pair to point upward and move in a horizontal plane (see Fig. 139). Each needle carries a thread; those that rise and fall pass alternately to the right and the left of those that move to and fro. By another plan a crank on

the bottom-shaft-wheel, and a connecting rod, rock a three-armed lever, the two remaining arms of which move selvage healds in opposite directions.

Some selvage motions twist one thread spirally round another; probably two of the best known of these were introduced by Sir Titus Salt and by J. Boyd respectively. The first named has a split-pinion A, Fig. 279, bolted on the crank shaft; it has sunken teeth and smooth flanges on either side. The rim of a wheel or ring B has two smooth outer edges, but teeth project from the centre; they are in the ratio of two to one in A, and the latter drives the former. The inner diameter of B is crossed by a spindle whose terminals are pressed into holes drilled in the ring. This spindle has a key fitted near one end, a pin hole drilled near the other, and a thread cut somewhat beyond its centre to carry two lock-nuts C, having milled heads. Two thread spools D are mounted upon the spindle, and a coiled spring E abuts against the end of one of them. The other spool has a key bed to receive a key in the spindle. The first spool would turn freely if the spring E was not compressed by the nuts C to thrust the spool against the holding pin—and thus retard rotation. Each spool has two threads wound upon it, and both spools are fixed upon the spindle, so that rotation will tend to wind the threads upon one as the others unwind.

On one face of the ring B two curved flanges F face each other. Inside each flange a tube passes through the ring B and protrudes on the flanged side; each tube has an eye drilled in the side that faces the spools. Both threads from a spool are passed through an eye, then one is led to the right and the other to the left. The wheel B is situated above A, with its front edge immediately behind the healds, and its centre midway between the top and

bottom lines of an open shed. B is kept in contact with A by a semicircular grooved cap G, which receives the teeth of B, and is bolted to any convenient bracket on a loom; hence the smooth edges of A, B and B, G touch.

Continuous twisting is obtained as follows: As B rotates, the flanges F are moved successively to face the centre of a shed; at this point the two threads nearest the healds are separated by a flange and tube, while the other pair, being farther from the healds, are nearer each other at that place; therefore the separated threads pass on the outside. But after a half-revolution of B the second pair are separated to assume the outer positions, and the first pair converge and move between them. Spinning twist in the spool threads must be in such a direction that rotation in B will not untwist and break them. To avoid trouble from this cause, two pairs of untwisted strands may be wound upon each spool; every revolution of the ring will then put a twist into both pairs. When this motion is properly adjusted it forms a neat and strong edge.

In 1863 J. Boyd fitted two circular spools loosely inside brass holders, and placed the holders in recesses on opposite sides of a central plate. The spools and their holders are retained in position by pressure from two external flexible plates. The top of each holder is bevelled to slope outward, and the under side to slope inward. A back plate holds what would in ordinary splits be the stationary threads; but here they move up and down in opposition to the spools. Thus, if for one pick these threads form a bottom shed, and the spool yarn a top shed, on the following pick they change places, in doing which they slide between the spool-holders and the middle plate. But as the threads move down again to assume their original positions, the upper bevels on the holders guide them

between the holders and the outer plates, therefore they twist round the spool yarn, forming one-half twist between every pair of weft threads. A tappet and spring give the vibrating motion. Boyd's device forms a good strong selvage, but both the last-named inventions are too costly for general adoption.

Fast or woven-in internal selvages appear to date from the invention of E. Riley in 1857. Since which time W. Simpson, in 1890, J. H. Clibran and G. Browning, also in 1890, E. Ashworth and A. H. Oldham, in 1891, and more recently others have turned their attention to the subject. In most cases an interval of $\frac{1}{2}''$ to $\frac{3}{4}''$ is left between the warp threads intended to form separate fabrics. The weft that crosses these intervals is cut in the centre of the gap, and turned back into the warps. Inside selvages are thus made of double weft, while the outer ones are of double warp. Much of the mechanism for this purpose is elaborate and costly, although some of it is comparatively simple. Irrespective of the quality of the work turned out by them, it is not economical to sever in the loom cloth that has to be printed or otherwise finished, for the cost of the processes subsequent to weaving is thereby increased.

Plain Side Selvages

Without increasing the number of heald shafts, plain selvages, or such as closely approximate to plain weaving, may be made on sateens, twills, and other weaves. This is done by means of a contrivance known as a boat.

A boat is shown in front and side elevations in Fig. 280. It consists of a piece of wood A, about 2″ long, straight beneath, but curved above. A hole D is drilled through A to receive a fulcrum pin. Two pieces of leather B, B′ are

nailed to the under side of A and turned round opposite ends; they are each about $1\frac{1}{2}''$ long, and wide enough to reach across the wood. A series of reed wires C, C′ are riveted in the leather, half-twisted, and bent over at the top. If a semi-plain selvage is to be made on a five-shaft sateen, one up and four down, two such boats will be re-

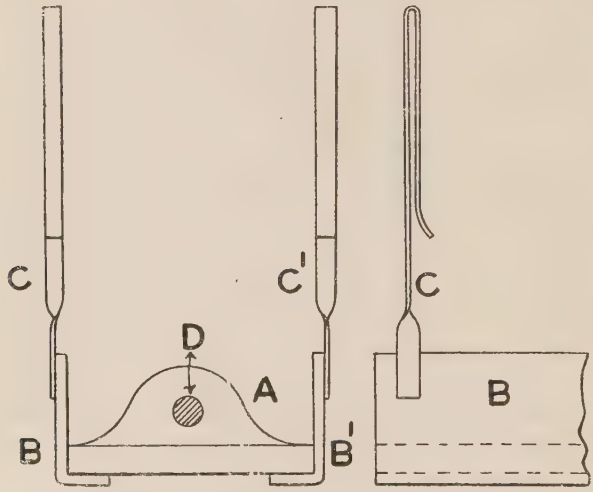

FIG. 280.

quired. Both are situated behind the healds at opposite edges of a piece, and below the warp line; they are supported upon pins bolted to the loom frame. Instead of drawing selvage threads into heald eyes, those intended for shafts 3, 4, 5 are passed through the loops of C′, and those for shafts 1, 2 go through the loops of C. Every thread from C goes over an eye in shaft 1 or 2, and every thread from C′ goes over an eye in shaft 3, 4, or 5. As a sequence, selvage threads in a rising shaft pull up one end of a boat

and depress the other end. The threads in the lifted end of A rise to a top shed, but those in the depressed end of A are pulled down to the race board. Since plain cloth cannot be made with five shafts, either two picks in each

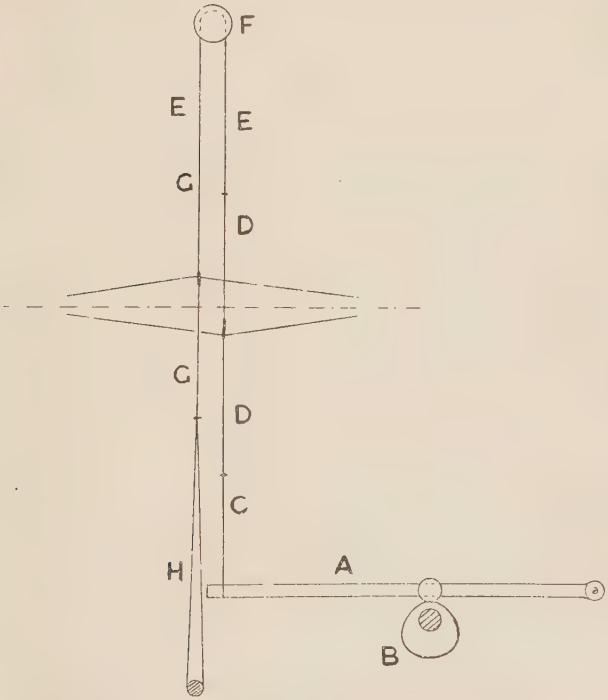

FIG. 281.

repeat of the sateen must be put into one selvage shed, or one pick in every five will be drawn up to the edge threads of the body, and therefore be lost to a selvage. By drawing the outside set of five threads in each selvage through the healds in the ordinary manner, the loss of a

pick in a selvage can be prevented. Also by suitably drawing the warp through the boat loops and over the heald eyes, twills and other satins than that taken as an example may be woven with perfect plain edges in some cases, and in others, with only slight modifications. A boat may also be made from a single piece of wire bent to the requisite shape. Instead of a boat, two sets of 16 mailed healds may be strung upon four wires, two above and two below, and severally connected to webbing. One web is passed over a flanged roller which is freely mounted upon a pin, and each end is attached to a separate wire. A second web is passed beneath a second roller and similarly united to one of the lower wires. These extra healds are placed behind the ordinary shafts. Warp threads are then drawn into all as for boats, and as the shafts rise and fall the threads that pass over eyes on the shafts, as for boats, impart movement to the selvage healds.

Another method of weaving plain selvages is illustrated in Fig. 281, where A is a light lever resting by gravity upon a cam B. From A a cord C ascends to a group of healds D that are threaded upon a wire. A second cord E is bent round a grooved pulley F and connected to the top loops of D. The opposite end of E is similarly connected to a second group of healds G, and the bottom loops of G are made fast upon a coiled spring, or a piece of stout elastic cord H. When the small face of B is uppermost, the lever A must be heavy enough to distend the elastic H and thus draw D down and G up. But when the cam B lifts A, the elastic H exerts sufficient force to restore the healds to their former positions. Hence if the group D contains odd threads, and G even ones, plain cloth will be woven. A single heald may be similarly employed to

manipulate a catch thread, for fabrics in which two or more picks are driven through the same shed, and where the weft would otherwise be withdrawn on the return of a shuttle.

PART XXV

ADJUSTMENTS IN POWER-LOOMS

SHORTLY after the power-loom became a commercial weaving machine an iron frame was substituted for a wooden one on account of greater compactness, strength, and cheapness. Compactness economises floor space, and strength is needed to resist shocks and vibrations that result from several pieces of mechanism acting intermittently. Although the parts of a loom work in harmony, and derive motion from a common source, they act and react upon each other to a considerable extent. A loom frame consists of two ends which are united by longitudinal and transverse rails. Where two pieces join, the framing should be planed; shaft bearings should also be bushed. The design of a loom frame determines the positions of the parts and their relations to each other; it affects the cost of production, by rendering it an easy or difficult matter to adjust, to repair, and to manipulate the machine. The cost of running a loom is influenced by the distribution of strength throughout the framing. If a frame is not strong enough to withstand the recurring shocks at the points where impact occurs, other parts will vibrate and break.

In height a frame should be such that a weaver may readily reach any part requiring attention. From 33″ in narrow looms to 40″ in wide ones is the usual height of a breast beam above the floor, and a back rest is frequently from $1\frac{1}{2}$″ to 3″ higher than a breast beam.

The stretch, or distance from front to back, varies with the nature of the material to be woven and the mounting of a loom. For calicoes it is from 35″ to 38″,

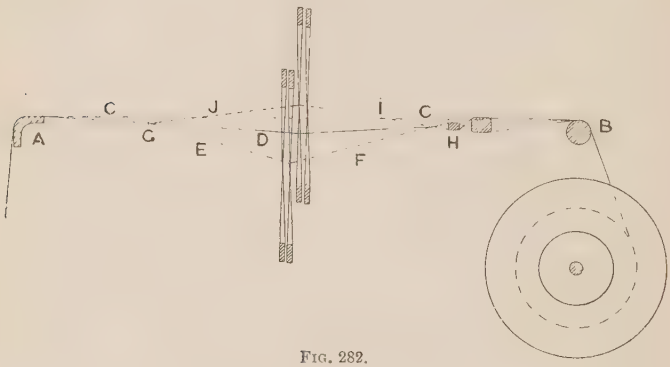

Fig. 282.

but narrow looms designed for heavy work are from 40″ to 45″, and broad looms from 52″ to 56″ deep.

The warp line is determined by the relative positions of the back rest B, Fig. 282, the breast beam A, the harness eyes, and the lease rods H. In practice the above-named parts are placed in different positions. Some overlookers fix A and B in one horizontal plane, and, with a lease in which two threads are over and two under each rod H, the distance between the first rod and the centre heald shaft equals that from the centre heald shaft to the cloth fell G. The heald eyes are then sunk below a straight line C, C, as shown at the closed shed line D. An upward movement

given to some warp, and an equal downward movement given to the remainder, will form in the bottom shed E, F equal angles before and behind the healds, and equal but smaller angles will be formed in the top shed I, J.

The angles being similar, equal strain will be put upon the warp on both sides of the healds, but more on the bottom than on the top shed. As a sequence, all threads in the lower line will be tight, while those in the upper one will be slack. This to some extent prevents the threads that pass in pairs through a reed, from running together in a fabric. But partially or wholly opening a shed intended for one pick before a reed drives the last one into position will assist in giving cover to a piece. For, during the operation of beating up, loose warp threads are separated from tight ones, and when in a cloth all threads will be equidistant. In Lancashire it is customary to fix the back rest upon $1\frac{1}{2}''$ higher than the breast beam, and to sink the heald eyes as before. But cover in cloth may be regulated by moving the lease rods. If they are set closer to the back shaft, a warp will be tightened, and if nearer the back rest, it will be slackened. This plan gives different angles behind and before the healds, and puts more strain upon a warp in one part of a shed than in another. When fabrics are woven face down, the bottom shed is made slack by dropping the back rest and raising the heald eyes. If inequality of tension be taken too far, corded cloth and broken warp will be frequent.

The correct bevel of a slay depends upon the length of the swords, the positions of the rocking shaft and connecting pins, the throw of the cranks, and the warp line. The warp line of an open shed determines the length of the swords, and if the latter are perpendicular when both reed and fabric touch, the position of the rocking shaft is also

determined. Cranks for narrow and medium looms move a reed $4\frac{1}{2}''$ to $6''$, and for wide looms from $6''$ to $12''$. When the requisite size of a crank and the length of a connecting arm have been obtained, the former's position is fixed in the frame by the rule given on pp. 456 to 458. The arms are connected to the swords, the cranks are placed on their bottom centres, and the slope of the race board is made similar to that of the bottom warp line. But the backs of the shuttle boxes must coincide with the reed.

After fixing the position of the crank shaft, that of the bottom shaft is proceeded with. It should be placed so that picking and shedding tappets may be readily adjusted. In looms designed to weave stout fabrics, the driving wheels are necessarily large, and heavy fly-wheels are fixed upon the main shaft, in order to accumulate sufficient energy to ensure steady turning as the cranks approach their bottom centres. But driving wheels must not be heavier than necessary, or as they revolve the energy stored up by them will be expended upon the frogs of a fast reed, and the brakes of a loose reed, whenever those parts are brought into action. All wheels should be well made and balanced, and as the teeth wear rapidly at the picking point, it is advisable to move the wheels periodically $\frac{1}{4}$ of a revolution, and again key them upon their respective shafts.

Since a crank shaft receives the motive power direct, and transmits it to other parts of a loom, all movements are regulated by this shaft. When the cranks are on their fore centres, beating up takes place, and as movement continues, other pieces of mechanism are brought into operation. In order to ascertain whether everything is working correctly, new looms are run for some hours before any attempt is made to weave with them. For this reason the

picking motion is adjusted first. If a cone pick is to be used, the tappets and cones should be in contact all the way round, the force should be properly directed, and the parts at both sides of a loom should be equal. A long shuttle box is also an advantage, as by guiding a shuttle it reduces any tendency to fly out. It is usual to set the mouth of a box at least $\frac{1}{8}''$ wider than the rear end. Unless picking arms and straps are carefully prepared and fixed, the arms will put a twisting strain upon the spindles as the pickers approach the forward ends of their traverse. A long arm will give too much leverage, but a short one will strain the strap, spindle, and picker. If in narrow looms an arm moves through an angle of 40 degrees, it will generally pass through about 30 degrees before it becomes parallel with a loom end; the remaining 10 degrees will cause it to slant inward. To find its proper length, the cranks are turned to their fore centres, the arm is drawn over the spindle centre longitudinally, and that part of the arm where the picking strap leaves it should be over the spindle axis. The length of a picking strap is obtained by turning the cranks on their back centres and moving an arm backward and forward; a picker should then slide freely from end to end of its spindle without the strap being unduly slack. If, however, it is necessary to lengthen or shorten a strap, this can be done by adjusting the strap itself, or by loosening the upper ring upon the upright shaft and moving the arm in or out; in either case the time of picking will be slightly altered.

Slow-running looms should begin to pick when the cranks are on, or a little past their bottom centres, but in fast-running looms it is usual to pick 10 degrees to 15 degrees before these points are reached. To time a pick, a picker is held against a box end, and the crank shaft is

turned until the picker begins to move. If the cranks do not occupy their proper positions, the bolts that pass through the picket-tappet slots are loosened, the shell and nose are moved in the required direction, and screwed tight. When a tappet nose faces the cone axis, the inner edge of the nose should be from $\frac{1}{8}''$ to $\frac{3}{16}''$ from the thick end of a cone. If more force is required, a tappet is moved nearer the upright shaft; but excessive force should be avoided.

Shedding and picking tappets may be correctly timed to each other, but not to the slay, in which event any alteration in the time of picking should be accompanied by a corresponding alteration in the time of shedding. This is done by loosening the crank-shaft bearings, lifting one wheel out of gear with the other, moving the tappet shaft in the required direction, and again making the bearings secure. Shuttles should be equal in weight and sufficiently heavy to overcome any side-pull from the weft. They should not be too large, or their increased bulk will necessitate a deeper shed. This will strain and break the warp. A large shuttle will hold a greater length of weft than a small one, but more time is needed to repair warp than to replace weft.

If a shuttle strikes a box end it will rebound, a cop will be thrown off, or a spool pin will be broken. If when the cranks are on their bottom centres a check strap holds a picker about 1″ from a box end, the foregoing defects will be avoided (see p. 377). Shedding tappets are set to act at different times to suit the fabric to be produced. If cover is unimportant, a tappet may be used on which less than $\frac{1}{3}$ of a pick is allowed for dwell. A shed should then be almost closed when the reed and cloth are in contact, but it must be fully open as a shuttle enters the

warp. Such a tappet is set by placing the cranks in their picking position, turning the tappet in its working direction until a treadle is fully depressed, and fixing it securely upon the shaft. Where cover is required, the cranks are placed on their top centres, the tappet is turned until both treadles are level and then screwed tight. In practice healds are level in all positions while the cranks move from their top centres until a reed is within $\frac{2}{5}''$ of the cloth fell. In case one tappet plate has a larger diameter than another, the treadle actuated by the largest plate is connected to the back shaft. If springs are used to reverse movement in heald shafts, they should all be equal in strength. Before attaching them, place each in turn upon a hook, and suspend a weight of from 4 to 7 lbs. from it; only those springs should be selected that stretch to the same extent—when supporting the same weight.

If a dobby of the Hattersley type is used, the bottom and top knives are set to move about $\frac{1}{4}''$ after liberating the hooks. When a peg is not acting, a hook is lifted $\frac{1}{4}''$ above a knife, and the driving crank is timed as for tappet shedding. For the adjustment of an oscillating tappet, see pp. 57, 58, and for that of single and double acting Jacquards, see pp. 207-209.

The back rest, the breast, and warp beams should be parallel with each other. A warp should be wound with an even tension, and be level all across. It is customary to set the beam flanges from 1″ to 2″ wider than the warp in the reed, but selvage threads should not be unduly oblique or they will be liable to break. Ropes or chains must be so coiled round the ruffles that regular slipping will occur, and the weights must receive frequent attention.

With a taking-up lever of the type illustrated in Fig.

263, a pushing pawl is set to drop into the hollow of a tooth in the ratchet wheel when the cranks are upon their back centres. The driving stud is then raised or lowered until a pawl takes one tooth as the slay moves forward. The cranks are turned to their fore centres, and a holding pawl is fixed about $\frac{1}{8}''$ past the bottom of a tooth (see p. 533).

In fast-reed looms the blades must clear the frogs by $\frac{1}{8}''$ to $\frac{1}{4}''$ when a shuttle is in its box, and they should be long enough to stop a slay when a reed is $2\frac{1}{2}''$ or more from the cloth fell. In practice the distance varies from $2''$ to $4\frac{1}{2}''$. The broader and deeper the shuttle, the greater the distance (see pp. 382, 383).

The steadying springs should be strong enough to prevent a loose reed from vibrating as a shuttle moves across. When the cranks are on their top centres, there should be a space of about $2''$ between the fingers and heaters, so that, in case of accident, sufficient room will be provided for the fingers to rise and slide along the upper inclines. In order that the fingers may hold a reed firm when in contact with a fabric, their tips must pass the front edges of the heaters about $\frac{7}{16}''$ (see p. 385).

When a shuttle is boxed at the driving side, and the cranks are upon their fore centres, a weft fork tappet should move the hammer lever. So long as weft is intact, the fork must clear the hammer head by $\frac{1}{4}''$, and pass through the grid without touching (see p. 491).

Multiple shuttle boxes should begin to move as the cranks reach their top centres, for then half a revolution is available for effecting a change and steadying the boxes before a shuttle is driven across. In one-sided box motions the pick following a change must be delivered from the multiple box side, and in all multiple box

motions the bottom of each box must coincide with the race board (see also pp. 416, 417).

The accompanying sheet, Fig. 283, shows that considerable variations from the foregoing adjustments are to be met with. The figures have been obtained from 32 looms made by 21 different firms.

When a warp is placed in a plain loom, cords are attached to the heald staves, and the healds are coupled to the roller motion to bring the shafts parallel with the slay. The reed is then mounted in the slay so that it shall not move vertically, but shall be free to move longitudinally, for this will permit the reed dents to face the heald eyes. Yarn is tied in bunches upon a rod, and cords or cloth connect this rod with the taking-up roller. The centre bunch is attached first, that is followed by the two outside bunches, and after them intervening ones are knotted upon the rod, care being taken to keep the threads equally tense. At half the lift both treadles should be in contact with the tappet, and in this position the healds are attached to them at a uniform height. The slay is moved to ascertain whether or no, in a fully open shed, the yarn touches the race board and misses the reed top; if it does not, the healds are adjusted vertically by means of the cords and straps.

Risk of shuttles being ejected may be minimised by attention to the following points: Fibrous yarn, knots with long ends, slack warp, uneven race board, small sheds, the bottom line too high, worn pickers, swells that give a twist to the shuttle as it leaves a box, and a rocking shaft that allows the slay to lift. All are fruitful causes of trouble.

Temples are fixed nearer to or farther from a reed, as the piece to be woven is light or heavy. Their inclination

varies, but as a rule they are set as near a reed as possible without touching, and with their front edge from $\frac{3}{16}''$ to $\frac{5}{16}''$ lower than the breast beam (see pp. 547-557).

Much wear and friction is caused by neglecting to lubricate the moving parts of a loom. But if lubricants are used too freely, grease is thrown upon the material being woven and about a weaving room.

PART XXVI

WEAVING SHEDS

In England looms are usually placed in a shed, because this type of building ensures good light, especially where Jacquards are used, solidity of foundation, freedom from vibration, better ventilation, and more uniformity in the humidity and temperature of the atmosphere than buildings of several stories. Ventilation and humidification are now regulated by law, and it is part of a factory inspector's duty to see that legal conditions are strictly complied with. A shed also admits of the most convenient arrangement of machinery and of easy supervision. The cost of building and gearing is small, and the carriage of material from place to place is facilitated. A shed may be built any width or length, and may adjoin other and more lofty buildings. The situation is of importance; it should be open to moist winds but protected from dry ones, and the subsoil should be clay. In making a selection consideration should be given to the cost of land, the cost of construction and equipment, and the scale of local taxation; the close proximity to a good and cheap supply of water and fuel,

ready access to the markets for raw material and finished products; but especially to a locality in which experienced operatives are plentiful.

In many cases the machinery employed for all processes between spinning and weaving is placed in a contiguous building of two or more stories, for by this means floor space is economised. In other cases a shed contains all the plant necessary to keep a concern in operation. Whatever the nature of the building, the machinery should be arranged to give the maximum of convenience with the minimum of supervision. Both will be appreciably affected if the material to be used can be prevented from travelling over the same ground twice. The complete scheme should be such as will keep down the cost of insurance.

Where Jacquards are used, sufficient height must be provided for suitably placing these machines over the looms, also because harnesses interfere with the free distribution of light. Shed walls A, Figs. 284 and 285, are 12′ 0″ to 16′ 0″ from the floor line to the base of the girders, and usually 14″ thick, unless one wall has to carry the gearing shaft C, in which event the thickness of that wall is increased to 18″ or 24″. If all the walls are of equal thickness, the shaft C rests upon columns built in one wall B. For the sake of cleanliness, it is desirable to isolate the shaft C from the shed by a thin wall.

The roof is supported partly by the walls, but principally by a series of cast- or wrought-iron columns D, erected upon a concrete and stone foundation. In sheds constructed with narrow bays, to weave plain cloth, cast-iron columns have a diameter of 5″ at the base and $4\frac{1}{2}$″ at the top, with a metal thickness of $\frac{5}{8}$″ at the former and $\frac{1}{2}$″ at the latter places. Since they only support a light roof and the shafting, this strength is ample. But for

Jacquard weaving the columns should be stronger, and have lips cast upon them from 7′ 0″ to 11′ 0″ above the floor line in order that they may support a network of light girders on which the Jacquards are to rest. An

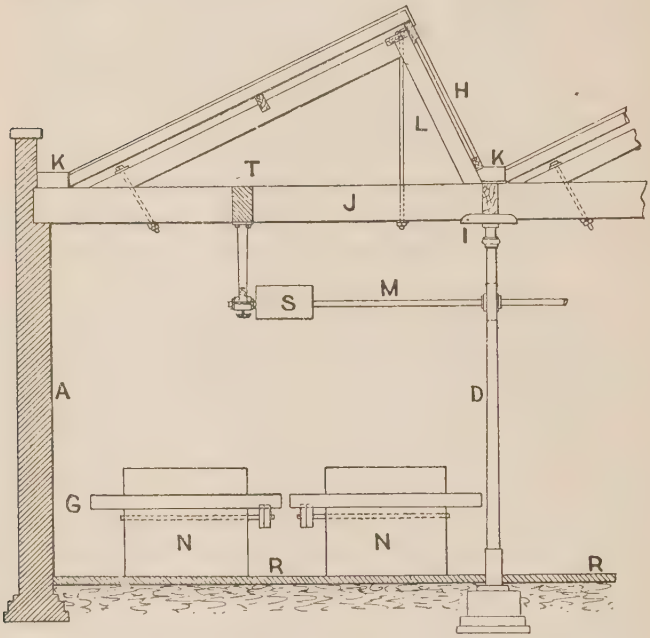

Fig. 284.

additional 1″ in diameter and $\frac{1}{8}$″ in metal thickness will in most cases suffice. The arrangement of columns depends largely upon the class of loom to be used; they are generally distributed to take four looms—two in length and two in width, and leave walking space between and round the looms. Narrow looms are from 3′ 6″ to 4′ 4$\frac{1}{2}$″

wide, averaging 4′ 0″ or 4′ 1″; and broad looms are from 4′ 7½″ to 5′ 8″ wide, but many are 5′ 2″ wide. A working alley E should be 20″ to 22″, a back one F not less than 16″ to 18″, and an end passage G 24″ wide; therefore taking the narrowest looms, we have 3′ 6″ × 2 = 7′ 0″ + 20″ + 16″ = 10′ 0″ from centre to centre of the columns that run from east to west. For a loom 4′ 0″ wide, at least 11′ 4″ should be allowed; in some new sheds filled with narrow looms 12′ 9″ is provided. Broad looms with two or three warp beams require a space of 14′ 4″ to 15′ 0″ between column and column. When planning a shed, extra space must be provided if two or more warp beams are to be used with each loom, also for tappets and dobbies when placed outside a loom framing, and for multiple shuttle boxes, or the work of the operatives will be unnecessarily difficult to perform. The looms in one shed may be of such varied lengths as to make it impossible to place them in a fixed position relatively to the columns. In old sheds, and in lines from north to south, the columns are from 15′ 0″ to 20′ 0″ apart, but in new sheds columns are greatly reduced in number. Thus, instead of arranging them, say 11′ 0″ by 16′ 9″ apart, as in the old plan, they are 22′ 0″ by 33′ 6″ apart. This provides for four narrow looms lengthwise and two end passages, between any pair of columns that run from north to south; also for four lines of looms with front and back alleys, between columns running from east to west. But alternate lines of shafting must be supported from the roof, and the roof beams and columns strengthened to guard against vibration. In a shed of the new type it is much easier to arrange looms of different lengths than in one of the old type, and the transit of warps is facilitated. Columns have a uniform arrangement, except where main passages traverse a shed.

At all such places at least 4′ 0″ should be allowed; they may be against the walls, or in the middle of a shed.

Weaving sheds are top-lighted, and the roofs are saw-toothed. Windows H run from east to west to give a northern light, which is the most uniform, and to prevent the direct rays of the sun from entering the building; the roof also forms a protection from east winds. Roofs are made of wood or metal, and each column is cast in the form of a shoe I, to take the horizontal wood, iron, or steel beams J that run from north to south. If the driving is overhead, cross beams T are placed at, and midway between, the columns. But if the driving is below the floor line they are fixed at the columns only. The beams J, T bind the columns and walls together; they support the roof, and from T and the columns D the shafting is suspended. Cast-iron gutters K rest immediately over the columns, but are at right angles to the beams J. They are connected to parts L, that make an angle approximating to 65 degrees with the water-level. These parts carry the upper portions of the roof, the gable of which forms a right angle. The steepness of each glazed portion H prevents the snow from collecting upon it in winter, and the sun from shining in too freely in summer. If in large sheds the only outlets were at the walls, it would be difficult to remove storm water fast enough, therefore the hollow columns are utilised as discharge pipes, and drain-pipes beneath the floor carry the water away. With this system difficulty is experienced in cleaning out the drains, and water is liable to find its way to the shafting and bearings. Much leakage may, however, be prevented by attention to the construction of the gutters, and the flashing under the windows. Another plan for removing rain water from shed roofs consists in fixing pipes beneath the gutters and parallel with the

beams J. Where water is first received, they are small in diameter but increase in area at each succeeding bay in proportion to the volume of water. Small manholes are provided at intervals, which allow the pipes to be readily cleaned out. In sheds of moderate size the roof may be pitched to slope from the centre to each outside wall at the rate of $\frac{3}{8}''$ to 1 foot. Each down spout is then large enough to remove half the water from one gutter.

Where a main driving shaft C is used, it is fixed against the gearing wall, and should be placed 9′ 0″ to 11′ 0″ above the floor line. It turns, by bevel wheels Q, all the line shafts M, that run parallel with and between alternate rows of looms N. In most cases line shafting is fixed transversely to the windows in order that the loom slays shall not throw shadows on the warps. Still there are sheds in which the shafting and gutters are parallel. If a shed is arranged for a given number of double rows of looms, an extra shaft is required. Some manufacturers prefer to have one or even two single lines of looms set apart for their least skilled weavers.

Main shafts are driven by steam engines, steam turbines, gas and oil engines, and electro-motors. On the continent of Europe looms have, for several years, been separately driven by motors and water turbines. In this country a shed is now being erected for separate driving by motors. Motion is conveyed from an engine through wheel gearing, ropes, and belts. Where wheels are used it is often advisable to place an engine at or near the centre of the gearing wall, and to elevate its bed so that the power may be passed direct to a wheel P on the shaft C. Or if the velocity is unsuitable, a second motion shaft is employed. In which event an engine wheel drives a pinion on the second motion shaft, and another wheel O

on that shaft transmits the power to P. The crank shaft of an engine and the main shaft C are then parallel, and equal power will be distributed on both sides of the wheel P. Instead of tooth gearing, ropes may be led from an engine wheel round a rope pulley on the shaft C. Every length of main shafting diminishes in diameter in proportion as the power to be transmitted is reduced; its dimensions are influenced by the nature of the looms to be driven and the distance from support to support. Generally speaking, loom shafting is stouter than that necessary for ordinary driving because of the unsteady action of these machines. Power is distributed to line shafts through bevel wheels Q, whose diameters should be such as will impart the required velocity, and cause each tooth of one to work by degrees in all the teeth of the other; a difference of one tooth is sufficient to ensure the latter. The line shafts M may be driven direct if the crank shaft of an engine is parallel to M, for half the ropes will be taken to pulleys on line shafts at one side, and half to those at the other side of the rope wheel. By means of similar ropes and similar wheels every shaft in a shed can be driven.

Looms are driven in various ways from shafting placed below the floor line. By one plan trenches, about 7 ft. deep by from 4 ft. to 6 ft. wide, are cut in the earth to contain shafts, driving drums, and supporting brackets, also to permit oilers and greasers to pass to and fro with a minimum risk of injury. Belts pass through holes in the floor to the loom pulleys, but the distance from centre to centre of the pulleys is several feet less than for overhead driving. This is a defect, as a belt must be tight in proportion as its length is reduced. On the other hand, it is claimed that less frictional electricity is generated, that

moisture from the trenches is continually carried through the belt holes, and that an under-driven shed is cleaner than an over-driven one. Another plan consists in excavating a basement under the entire shed. The shed floor then rests upon beams 8 ft. apart, beneath which an ample number of columns is provided to prevent vibration. The cost of building such a shed is much greater than for over-driving or under-driving by the trench system. The space thus provided is, however, utilised as a storeroom for warp and weft, and as a general store.

In order to give the machinery a firm base, a shed floor R is covered with heavy slabs of stone. Looms are made right and left handed, to bring the driving pulleys together, and are placed back to back. They are formed into groups of four, and two rows are driven from one line shaft; the latter is fixed to the columns D, and further supported by hangers from the roof beams T. Each group is driven by a drum S, 20″ to 24″ wide by 15″ to 20″ in diameter, which is capable of carrying four driving straps. Or two narrower drums are fixed on opposite sides of the shaft bearings, and as close together as possible. Each then drives a pair of looms by means of pulleys that vary from 8″ to upwards of 18″ in diameter, according to the required speed of a loom. In order that the loom ends may give straight lines of machinery, the crank shaft of one is made longer than that of its fellow by at least the width of two driving pulleys. Loom shafts are set parallel with the line shafts in the following manner: A plummet is dropped from different points along the first line shaft, and where it touches the floor a permanent mark is made with a chisel. A chalked cord is stretched over two such marks, lifted at the centre, and suddenly liberated, when a straight white line is left on the floor, and it must be extended from

wall to wall. Similar lines may be made below alternate shafts, after which two marks are made, 10′ 0″ to 12′ 0″ apart, upon one of the lines; each is used as a centre from which two intersecting arcs are described on both sides of the line. A chalked cord is stretched over the points where the arcs intersect to make a line at right angles to those already traced. From these lines the positions of the loom feet can be obtained, care being taken to fix them so that the pillars will not unnecessarily obstruct the back alleys. A long straight-edge, with a spirit-level on the top of it, is laid upon a loom in various positions, to ascertain if packing is required beneath the feet; if so, pieces of wood are cut to the required size, the positions of the foot holes are marked, the loom is removed, holes are drilled in the flags, and dry wooden pegs are tightly driven into them. The loom is then put back into position, and long nails are driven through the feet into the wooden plugs; the latter swell with the moisture of the floor and hold the loom securely. By another plan, after the positions of the loom feet have been defined, and holes drilled in the flags, projecting studs from loose feet are dropped into them, and the loom is placed upon the recessed loose feet.

In addition to the calculations given for healds on pp. 12 to 19, for shedding on pp. 31, 32, 61 to 64, 82, 309, 310, 317 to 319, for picking on pp. 338, 339, for beating up on pp. 460 to 466, for reeds on pp. 469-470, and for taking-up motions on pp. 534 to 536, two velocity examples are added. Namely: If a line shaft makes 130 revolutions per minute and is to drive a loom at the rate of 200 revolutions per minute, by means of a loom pulley 9″ in diameter, what must be the diameter of the driving drum?—

130 : 200 : : 9″ : 13·9″, the diameter required.

Also, if a line shaft makes 140 revolutions per minute, and

is furnished with a drum 15″ in diameter, what must be the diameter of the loom pulley to give 220 picks per minute?—

220 : 140 : : 15″ : 9·55″, the diameter required.

So many small matters connected with a loom require close attention, that successful weaving depends upon strict attention to details. But most of these can only be dealt with as they arise in practice.

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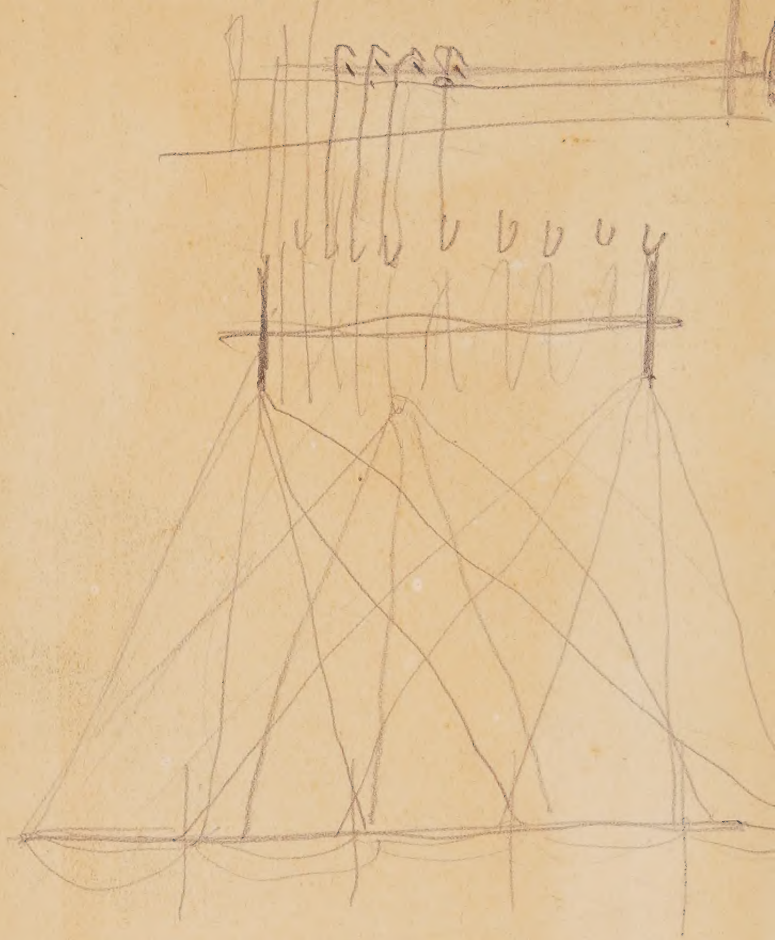

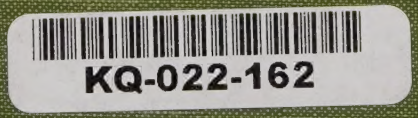
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